AN ABSTRACT OF THE DISSERTATION OF

Michael P. Fisher for the degree of Doctor of Philosophy in Rangeland Resources presented on September 22, 2004.

Title: Analysis of Hydrology and Erosion in Small, Paired Watersheds in a juniper-sagebrush Area of Central Oregon

Abstract approved:

Redacted for Privacy

John C. Buckhouse

Current research indicates that the expansion of western juniper can inhibit soil water retention, storage and prolonged releases from watersheds. This phenomenon is of great importance in eastern Oregon, as western juniper is encroaching into sagebrush/grass communities with a correlated reduction in herbaceous ground cover, resulting in reduced infiltration rates and increased soil loss. A paired watershed study for the purpose of monitoring water quality/quantity as affected by western juniper in the Camp Creek drainage, a tributary to the Crooked River, was established in 1994.

Monitoring methods consisted of annual and semiannual measurements of hillslope soil movement, channel morphology, including total cross-sectional area, scour and deposition, channel discharge, depth to groundwater, and precipitation. Channel discharge was established using a 3,0 H-flume with a pressure transducer and stilling well and data logger. Changes in

channel morphology were determined using 25 permanent, channel cross-section plots per watershed. Hillslope erosion processes were determined using 12 transects of 3 sediment stakes per watershed, located within gullies of subwatersheds.

Data showed the two study areas to be well correlated with regards to soil movement, both within the main channels and in the subwatersheds (hillslopes). Some of the geomorphometric properties are similar (not statistically different) and differences in other parameters can be explained. Channel discharge appears to be significantly different in intensity, frequency, and duration of flow. These differences in surface discharge may be explained as further data collection of subsurface flow analysis in conjunction with sampling of springs located in each watershed are conducted.

Analysis of Hydrology and Erosion in Small, Paired Watersheds in a Juniper-sagebrush Area of Central Oregon

by
Michael P. Fisher

A DISSERTATION

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APPROVED: Redacted for Privacy

Major Professor, representing Rangeland Resources

Redacted for Privacy

Head of the Department of Rangeland Resources

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Dean of the Graduate School

I understand that my dissertation will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my dissertation to any reader upon request.

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Michael P. Fisher, Author

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The author expresses sincere appreciation all contributors in this project. This has been an adventure to say the least. I cannot begin to express how grateful I am to all of my friends, family and cohorts that have been patient and supportive of me throughout this process.

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INTRODUCTION

PURPOSE

The purpose of this study was to use two similar watersheds in the western juniper zone to quantify and understand changes that are hypothesized take place due to vegetation-type conversion. This project is phase one of a two-phase project. Phase one (1993-2003) included the instrumentation and calibration of the paired watersheds whereas phase two will encompass the treatment and follow-up analyses. The first phase involved providing the watershed hydrology description and analysis of the two basins based on vegetation, soils, topography, geology, channel morphology, streamflow, local climate, and erosive processes. The calibration period, which was a continuation of the first phase, involved continued data collection for a period of approximately ten years (1994-2003) at which time one of the watersheds will be treated and the other will act as a control based on the calibration period. Phase two, begins when one of the two watersheds is treated, providing for post-treatment data analysis.

Western juniper (*Juniperus occidentalis*) stands will be modified in the treatment watershed in order to shift the vegetation structure from a juniper dominated to a shrub/grass dominated system. During the fall of 2005 all post-Euro-American established, western junipers will be felled. Old growth (pre-European established trees) will not be cut. Downed woody material should provide safe sites for grass seedling establishment as well as promote the capture of sediment and minimize temperature extremes at the soil surface. This conversion of vegetation type should assist in the function of the water cycle by providing a more uniform and stable environment for capture, storage, and beneficial release of water (Buckhouse 1999). By converting the understory from bare ground to a grass and shrub cover, the site should retain moisture more readily and release the moisture into the system on a more stable and sustained basis.

During the calibration period, monitoring has quantified differences in streamflow quality and quantity. Differences in water quality were studied indirectly as a function of hillslope erosional processes and changes in channel geomorphology. The hillslope erosion was analyzed by evaluating the changes in vegetation versus bare soil composition, distribution and density, and soil status relative to increased or decreased erosion. Erosion and sedimentation were analyzed by studying changes in channel morphology in the primary channel of each watershed. Differences in streamflow quantity focused primarily on water yield within each watershed and comparisons between the two watersheds.

The vegetation conversion portion of this project focuses on the conversion of a western juniper overstory with relatively high percentages of bare ground interspaces to a grass/shrub system with minimal bare ground. One of the primary differences expected is a change in the distribution of biomass over the watersheds

(Bates et al. 1999). Biomass distribution in western juniper-dominated systems tends to be elevated above the ground and moves toward patchiness of vegetative cover with larger concentrations of bare soil. The soil portion of phase two of the study, will focus on whether or not the erosional forces are stronger in the western juniper-dominated system (control) as compared to the treated system.

RATIONALE AND SIGNIFICANCE

Study application

Many different management techniques have been used to control the encroachment of western juniper on rangelands in central and eastern Oregon (Buckhouse 1984; Kropf et al. 1984; Bedell 1987; Vaitkus et al. 1987; Miller et al. 1992). However, with additional research many unknowns could be quantified (Bedell 1987). This study allowed for intense monitoring of a western juniper-dominated system on a watershed scale that acknowledges both the uplands and the stream channel.

Previous studies in pinyon/juniper systems in the southwest have focused on either the uplands or the drainage bottoms. According to Wilcox (1994), runoff amounts can vary with scale, so by obtaining measurements in both the uplands and the drainage bottoms, understanding the origin and extent of runoff will be more likely.

Land managers are attempting to confront the issue of western juniper encroachment with management techniques that are only partially understood (Eddleman

1999). The long-term results of this study are expected to provide very useful scientific data relative to understanding and managing western juniper encroachment and the hydrological cycle.

In the past few years, there has been increased public awareness and concern over these depauperate, encroached western juniper systems and their influence on anadromous fisheries habitat as well as overall rangeland system health. Careful analysis and monitoring will provide specific insight into western juniper woodlands watershed functions, processes, and management, allowing managers to place their time and efforts where they can get the most cost-and time-efficient results relative to these concerns. However, it may be entirely possible that at the scale studied here, western juniper treatment will result in more on-site than off-site changes with little or no direct effect on stream flow. Due to the length and intensity of this study, subtle and indirect effects may surface throughout the duration of the study period.

Goals and Objectives

The long-term goal of the complete project is to provide a documented analysis using paired watersheds to determine what effect western juniper encroachment has on streamflow quality and quantity. Within this goal are the following objectives:

1. To determine to what degree western juniper encroachment affects sediment yield.

2. To determine western juniper impact on water yield.

3. To determine effects of vegetation conversion following western juniper treatment.

4. To develop watershed management models concerning management of western-juniper-dominated systems relative to sediment production, water yield and vegetation conversion.

5. To examine the nature of the dominate erosion processes.

The short-term goal has been to provide a watershed hydrology analysis on a paired watershed scale to determine to what degree Mays and Jensen watersheds are similar and different. That is, to provide baseline data on both watersheds in order to capture the background variability so that the treatment effects can be distinguished with as much statistical significance as possible. Included in this goal are the following general objectives for each watershed:

1. Monitor channel flow via flumes.

2. Develop baseline vegetative data.

3. Obtain stream cross-section measurements to determine the area of active channel.

4. Determine geomorphologic channel dynamics, using annual cross-section data.

5. Maintain permanent sedimentation stake measurements within the sub-drainages.

6. Establish baseline data for subsurface flow.

The following comparisons were tested in this PhD study:

1. Percent canopy cover of western juniper is not different between Jensen and Mays watersheds.

2. Percent canopy cover of perennial grass is not different between Jensen and Mays watersheds.

3. Percent bare soil is not different between Jensen and Mays watersheds.

4. Sub-drainage erosion processes are not different between Jensen and Mays watersheds.

5. Main channel erosion processes are not different between Jensen and Mays watersheds.

6. Seasonal discharge is not different between Jensen and Mays watersheds.

7. Geomorphometric characteristics such as flatness, slope, roughness and organization are not different in Jensen and Mays watersheds.

8. Stream channel profiles are not different between Jensen and Mays watersheds.

9. Stream orders are not different between Jensen and Mays watersheds.

STUDY AREA DESCRIPTION

LOCATION

The study area is contained within the Crooked River Drainage Basin, which consists of approximately 7,242 square kilometers of forest, agriculture, and rangeland (Whitman, 1999). The study area is located in central Oregon approximately 80 kilometers southeast of Prineville and approximately 40 kilometers northeast of Brothers along U.S. highway (Figure 1). The legal description is section 32, 33, T18S, R20E and section 5, T19S, R20E Willamette meridian. Mays and Jensen Canyons are the watersheds that encompassed within the study area.

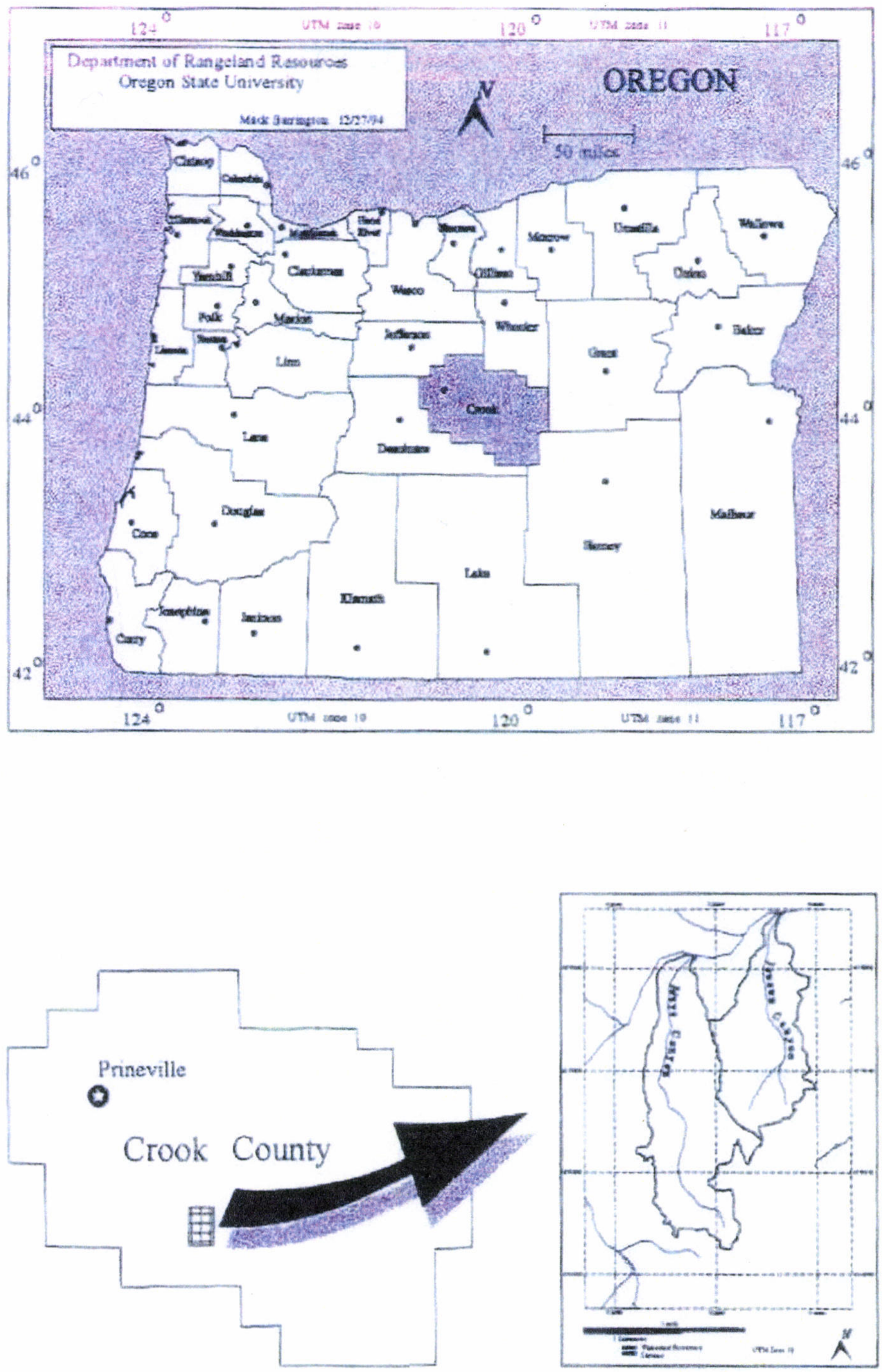


Figure 1. Map of study area location.

The study area contains approximately 113 hectares in Mays Canyon and 106 hectares in Jensen Canyon (Figure 2). The Mays and Jensen canyons drain into the West Fork of Camp Creek (which in turn drains into the South Fork of the Crooked River) and include both private and public land. Within the study area, the private lands are owned by the Hatfield High Desert Ranch; the federal lands are managed by the Prineville District of Bureau of Land Management (BLM).

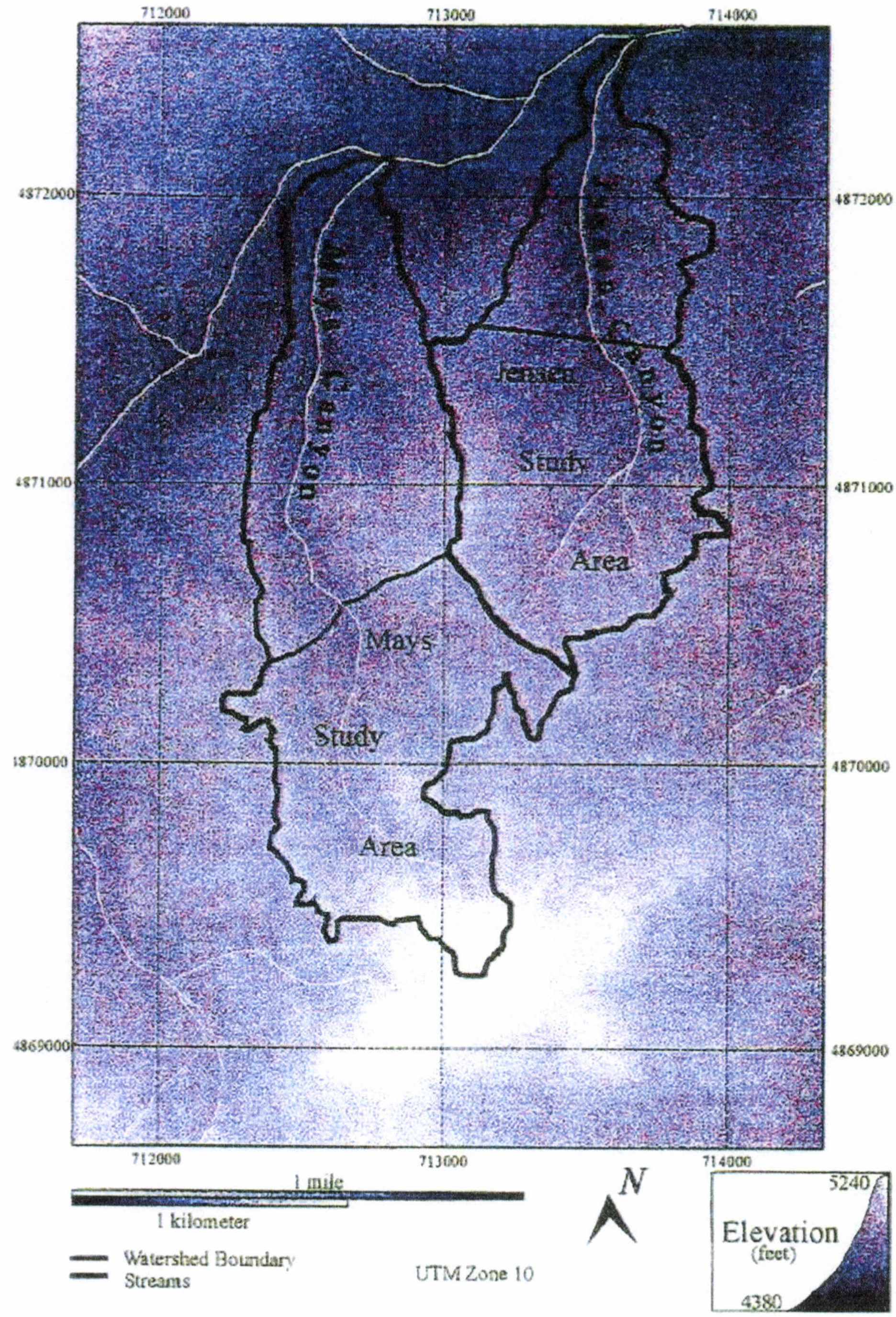


Figure 2. Digital elevation model of study area.

REGIONAL CLIMATE

Climate in the Crooked River Watershed plays an important role in western juniper's ability to expand within its native habitat. The study is located within the John Day Ecological Province as defined by Anderson and others (1998). The John Day Province is characterized by annual precipitation ranging from 10 inches per year (25.4 centimeters per year) at the lower elevation sites to 30 inches (76.2 centimeters per year) in the higher elevations with an average of 13 inches per year (33.0 centimeters per year).

The highest period of precipitation is during the month of December, with only 28% falling during the growing season of April through June (Anderson et al. 1998). This is especially pertinent when understanding the physiology of western juniper and its ability to utilize this precipitation regime to its competitive favor, partly due to the soil moisture storage relative to the time of use. Moisture that falls during the cool season tends to recharge the deep soil moisture storage, whereas warm season (growing season) moisture tends to supply the shallow portion of the soil profile (Miller 1989).

Woody plants such as western juniper tend to be deep-rooted and take advantage of cool season moisture giving them the competitive advantage in this type of moisture regime (Miller 1989). Shallow soil profiles also give western juniper the competitive advantage. When moisture stressed, western junipers will develop an extensive lateral root system for water absorption (Miller 1989). Gedney et al (1999) showed that the bulk of western juniper forests (52.5%) in eastern Oregon exist in a precipitation range of 10-15 inches per year (25.4-38.1 centimeters per year), (Table 1).

Table 1. Precipitation classes in inches relative to the distribution of two different western juniper classifications. (source: Gedney et al. 1999)

Annual precipitation class	Juniper forest	Juniper savanna	Juniper forest and savanna
Inches		Percent	
5.0-10.0	10.1	10.5	10.4
10.0-15.0	52.5	52.3	52.4
15.0-20.0	23.6	25.7	24.8
20.0-25.0	9.6	8.7	9.0
25.0-30.0	3.4	2.0	2.6
>30.0	0.9	0.9	0.9
TOTAL	100.0	100.0	100.0

Precipitation is, in some cases, directly associated with topography and terrain features (orographic influence). Miller (1999) states that western juniper decreases in occurrence as elevation increases. This is a two-fold effect of the associated vegetation taking on an equal or greater competitive advantage at the higher elevations, as well as western juniper being more susceptible to the shorter growing seasons and harsher conditions.

This region also has a tendency to maintain low temperatures throughout the non-growing season, ranging from -7° to 3° Celsius (Anderson et al. 1998). Again, this can work to the advantage of western juniper, given its ability to transpire in conditions only slightly above freezing.

STUDY AREA WEATHER

Long-term weather data more specific to the study area was obtained from the Barnes weather station, (Oregon Climate Service), located approximately 11 kilometers northeast of the study area. The 1962-2003 station precipitation data shows annual precipitation averages 330 millimeters. Data shows the wettest year was 1983 (559 millimeters) and the driest year, 1964 (152 millimeters). These precipitation extremes demonstrate the potential for a high degree of annual variability and a bimodal precipitation pattern. Most precipitation falls as snow during November through February with the remainder falling during convectional thunderstorms in the summer months of May through August (Figure 3). The normal growing season for this area is March through July with fall green-up occurring following precipitation in late September or early October. The 40-year data shows December and January to be the coldest months, averaging -2° Celsius, and July and August the warmest averaging 18° Celsius (Figure 4).

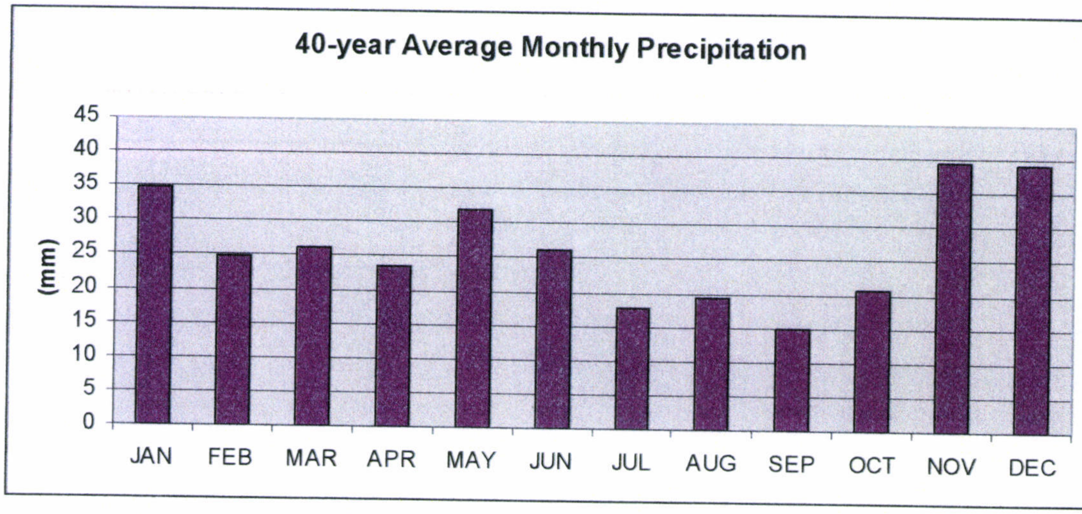


Figure 3. 40-year monthly average precipitation in millimeters from Barnes Weather Station.

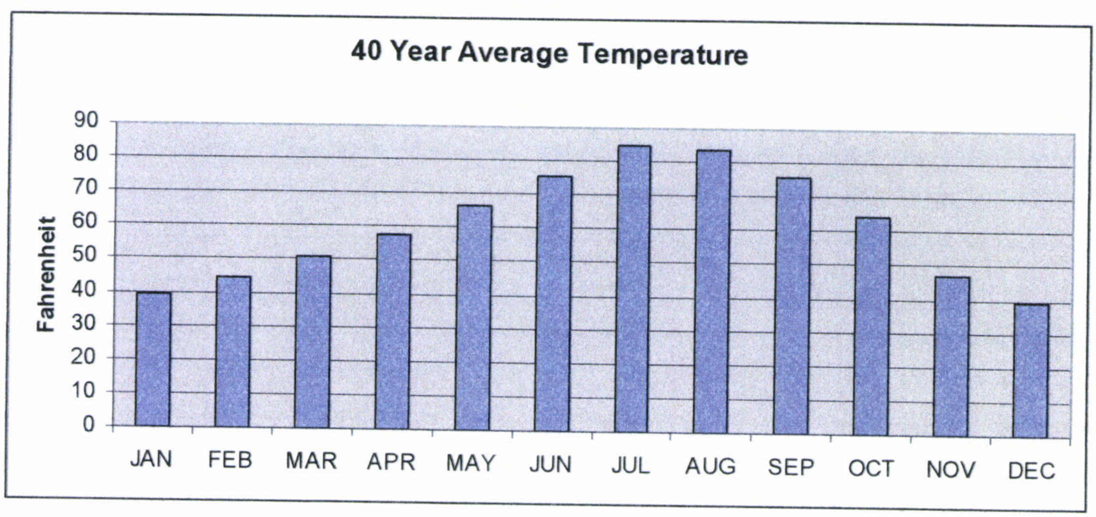


Figure 4. Monthly average temperature in degrees Fahrenheit from Barnes Weather Station.

GEOLOGY

The geology of the Crooked River Basin also plays a significant role in the establishment and expansion of western juniper. The Crooked River Basin is classified as being included in the John Day Ecological Province (Anderson et al. 1998). This classification can be defined in geological terms as containing John Day, Mascal and Clarno formations. The primary formations in the Crooked River Drainage are the John Day and Clarno formations. These formations were characterized as being made up of rhyolite ash deposited from the adjacent Cascade Range during the Oligocene era 20-30 million years ago (Alt and Hyndman 1978). More specifically the Clarno formation is made up of basaltic to rhyolitic, mostly andesitic, flows, domes, breccias and small intrusive masses (Gordon 1996).

The study area primarily consists of Clarno formation, with unconsolidated alluvium comprising the drainage bottoms. Tuffaceous facies made up of andesite and basalt minerals with secondary feldspar are included in this formation and specific to the Ochoco/Maury Mountains. As evidenced by the fossil plants and vertebrates located in nearby Logan Butte, this geology can be dated to the Eocene and early Oligocene period (Walker 1977).

SOILS

Because of the complex geology of the Crooked River Watershed, as expected there would also be at least moderately complex soil types present. The Simas, Westbutte and Madeline are three of the series that make up the bulk of areas currently occupied by western juniper. The Simas, Westbutte, and Madeline series cumulatively represent a multitude of soil associations, that when combined with a moderate to steep slope and minimal herbaceous vegetative cover can facilitate significant soil erosion. Gedney et al. (1999) uses soils to delineate areas of greater western juniper establishment (Figure 5). Classified by temperature and moisture regime, this chart shows the more-likely locations of western juniper.

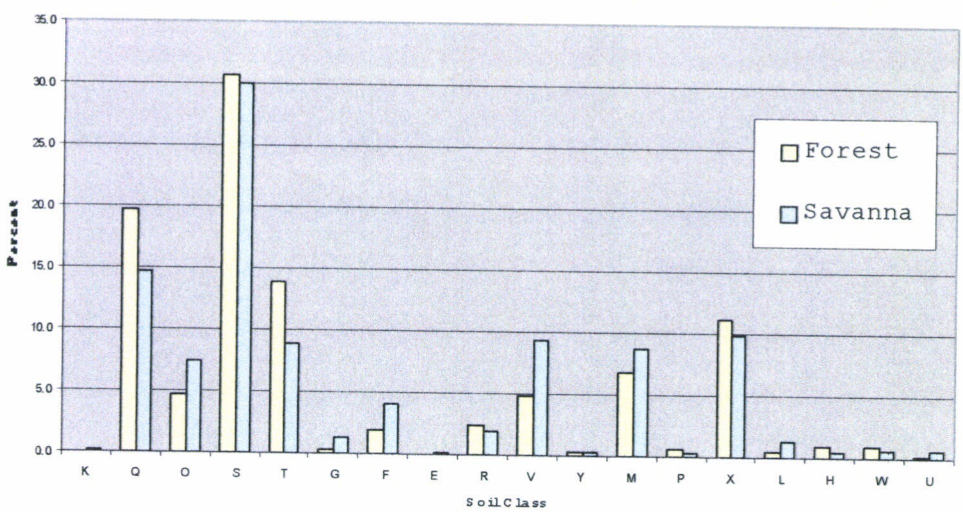


Figure 5. Distribution of area of western juniper forest and savanna by soil class, eastern Oregon, 1988. (Source: Gedney et al. 1999)

The classifications in Figure 1 can be more clearly understood by referencing Appendix R for the classification definitions.

The graph showed that 68.3% of the western junipers were found on only four soil classes, Q, S, T, and X.

All four of these classes can be described as having Aridic-Xeric or Xeric-Aridic features. This can be simplified by stating that juniper appear to do best on dry sites where the bulk of the moisture comes in the winter.

This classification also suggests western juniper is more commonly located on prominent landforms in the landscape. In this case, 97.2% of the western juniper was found on terrace and flood plains, grass-shrub uplands, and plateaus and uplands.

There were no published soil surveys for the study area, although there is one in progress. Preliminary analysis indicated the study area was comprised of three primary soil series (Westbutte, Madeline, and Simaton) with multiple inclusions of other series.

The Westbutte very-stony loam and Madeline loam series make up about 80% of the study area with Simaton gravelly-silt loam accounting for most of the remainder (Appendix A). The Westbutte series is derived predominantly from weathering of lava rocks and is characterized by slopes of 3-30% on more-northerly-facing aspects. The Madeline loam series is formed in material derived primarily from tuff, basalt, and volcanic ash. This series is characterized by 3-30% slopes located predominantly on southerly aspects. The Madeline series has a shallower rooting depth (30-50 centimeters) and a greater potential for runoff and erosion than the Westbutte series. The upper end of each watershed contains Simaton gravelly-silt loam series. This series is characterized by rapid runoff and high erosion hazard. This series can generally be found on hillslopes and is formed of colluvium from old, clayey, semi-consolidated sediments. The Simaton series also has a high degree of clay content relative to the other series. Inclusions of Choptie, Choptieloam and Embal loam series are also found in the study area (Thomas 1995).

VEGETATION

Study area vegetation consists primarily of sagebrush steppe/bunchgrass communities with localized sites of indigenous western juniper woodlands. The sagebrush steppe and bunchgrass types express a western juniper woodlands appearance, demonstrated by the high degree of western juniper encroachment, as seen in a comparison of 1950 versus 1989 aerial photos.

Western juniper comprises the majority of the overstory. The shrub layer is dominated by mountain big sagebrush (*Artemisia tridentata, sub species vaseyana*) and green and grey rabbit brush (*Chrysothamnus viscidiflorus* and *C. nauseosus*), with a mixture of perennial grasses and forbs making up the understory.

The grass component consists of scattered bluebunch wheatgrass (*Agropyron spicatum*), Idaho fescue (*Festuca idahoensis*), prairie junegrass (*Koelaria pyramidata*), Sandbergs bluegrass (*Poa secunda*), and Indian ricegrass (*Oryzopsis hymenoides*). The forb component is comprised mainly of buckwheat brush (*Eriogonum spp.*), and wild-daisy (*Erigeron spp.*). Antelope bitterbrush (*Purshia tridentata*) and wax currant (*Ribes cereum*) are present to a minimal extent within the study area. See Appendix B for a common species list.

LITERATURE REVIEW

INTRODUCTION

Western juniper has been steadily increasing its range in Oregon for the last 100 years (Eddleman 1987; Gedney et al. 1999; Miller and Rose 1999; Miller et al. 1992). According to Miller (1992), Central Oregon may contain up to 1,145,670 hectares of western-juniper-dominated plant communities.

THE HISTORY AND EXPANSION

Western juniper expansion has played a critical role in shaping the environment in central and eastern Oregon. Prior to discussing this expansion, it is first useful to discuss some of the more historic behavioral patterns of western juniper relative to expansion. Western juniper was at, or above, the current levels of density in eastern Oregon approximately 600 years ago (Miller, 1989). According to Miller and Wigand 1994, western juniper has been present in eastern Oregon for 4,000-7,000 years, but was located mainly in open, sparse, and savanna-like stands. Miller (1989) suggests that the bulk of expansion has occurred since Euro-American settlement in the mid-late 1800's.

Gedney et al. (1999) discusses how western juniper has expanded throughout its range in Oregon. Although this study was not specific to Central Oregon, this information is useful in understanding what has occurred, and is occurring, concerning western juniper rate of spread. In this analysis, there were varying periods that were studied. From 1650-1800 the rate of western juniper stand establishment increased from 2,900 acres per year to 8,200 acres per year in the period from 1800-1850. Gedney et al. (1999) established that 37% of the present western juniper forests established during this period.

From 1850 through 1900, there was a dramatic increase of 23,100 acres per year in stand establishment. The last period addressed in this study demonstrated that between 1900 and 1940 the rate of western juniper stand establishment decreased to 6,000 acres per year. Although the trees established during this period account for only 1/10 of the current western juniper stands, according to Gedney et al. (1999). This represented, nonetheless, still twice the rate of establishment of pre-Euro-American influence.

Further information from this study shows there to have been three successive drought periods totaling more than 85 years worth of drought during a 200-year period. They state that approximately 75% of the currently-established western juniper stands originated between 1859 and 1918 and average 70-130 years of age, and established during the drought free periods.

Miller and Rose (1999) also looked at western juniper expansion in Oregon, focusing on the High Desert Province area, specifically the Chewaucan Basin. This study demonstrated a dramatic increase of western juniper from 1875 to present day with a peak in establishment from 1905-1915. This study paralleled Gedney's study by showing that in the closed stands of western juniper, 78% of the trees were established between 1885 and 1925. It should be noted that the Miller and Gedney studies differ in scale, purpose, and methodology.

Gedney et al. (1999) focused on the stand level rather than individual tree and classified stands into two classes, including western juniper forests and western juniper savanna. The western juniper forests were delineated as stands with trees greater than 10% crown cover whereas those with less than 10% crown cover were classified as western juniper savannas. However, only trees greater than 5 inches (12.7 centimeters) in diameter at breast height (dbh) were tallied. The exclusion of western juniper trees in the seedling-to-sapling stage ignored a significant number of trees and affected the results of the study. The results are impressive enough, but reported density would even be higher if the smaller diameter trees had been included. Conversely, their study was extensive in area and necessitated simplified sampling. Miller and Rose (1999) studied a smaller area but focused on individual tree establishment.

An examination of western juniper establishment in Oregon since the mid-1900's shows a substantial increase in stand extent from 466,000 acres to 2.2 million acres. Gedney et al. (1999) showed a five-fold increase in western juniper forests between 1936 and 1988 (Table 2) within the Deschutes River classification system. This information coincides with data from Miller and Rose (1999), which showed a similar increase. Their study showed a constant establishment of western juniper in open stands from 1900-1995 with the exception of 1935-1945. Lack of establishment during this period is attributed to the drought period prior to and during the early portion of this period. Miller and Rose (1999), also maintain that western juniper will maximize its establishment during wet, cold seasons, and decrease its establishment during the dry, warm periods. This particular phenomenon was determined using growth-ring analysis.

Table 2. Estimated area of western juniper forest by region, 1936-1988, eastern Oregon. (source: Gedney et al. 1999)

	Inventory date			
Region	1936	1988	Change	
	Thousand acres		Ratio	Thousand acres
North Blue Mountains	0	2	--	2
Deschutes River	314	964	1:3	650
South Blue Mountains	20	829	1:41	809
Klamath Plateau	86	444	1:5	358
Total	420	2,239	1:5	1,819

WESTERN JUNIPER AND WATER

An increase in western juniper density has been shown to modify water yield and water quality through decreased infiltration and increased sedimentation (Gifford 1973; Buckhouse and Mattison 1980; Baker 1984, Buckhouse 1999). Western juniper encroachment is thought to have converted a vast amount of productive rangeland into western juniper woodlands that are often characterized by low forage values and high erosion rates (Bedell, 1987).

Bedell (1987) suggested that western juniper has both the morphology and the physiology necessary to be a very competitive plant in the semi-arid region. These attributes provide western juniper with a year-round competitive edge (Miller 1984). The leaf morphology, leaf structure, and root distribution of western juniper allows it to photosynthesize under conditions in which other plant species are dormant (Miller 1984). According to Miller, even under cool conditions 100 western juniper trees per acre, with a 12-inch (30.5 centimeter) average diameter, can utilize 200-250 gallons (757-946 liters) of water per acre per day. Although this figure is dependent upon factors such as humidity, available soil moisture and both air and soil temperature (Miller 1984; Miller et al. 1987), it nevertheless accounts for a very large amount of water - an important AND scarce, resource in semi-arid systems.

Western juniper has a unique growth form that allows it to intercept relatively large amounts of the available precipitation and direct it to the tree bole as stemflow. During extreme precipitation events, stemflow can create a type of erosion known as rill erosion (Larsen 1993). Rill erosion is caused by an intense volume of water that is distributed from the stem of the tree through the litter layer under the canopy and onto relatively unprotected (bare) soil of the interspaces. More commonly, rill erosion occurs as a result of the interspaces being void of vegetation. With increased slope, these rills increase in size and length and are thought to have a significant influence on the sediment loads deposited in the streams.

Throughout central and eastern Oregon, land managers have reported a loss of springs during a period of western juniper encroachment (Eddleman and Miller 1991). After western juniper population was reduced, some of the same land managers noticed spring re-establishment along with an increase in forage production (Eddleman and Miller 1991; Kropf et al. 1984). Although cause and effect has not been clearly established, to assumption is that juniper has been a primary influence.

Studies relating western juniper occupation to streamflow have been done almost exclusively in the southwest United States (Bates 1928; Baker 1984; Collings and Myrick 1966; Clary et al. 1974; Stevens et al. 1991; Wilcox 2002; Hastings et al. 2003). Only four of these studies have used paired watershed approaches, and they have yielded mixed results. Although studies concerning western juniper occupation effects on watershed in the northwest have been completed (Buckhouse and Mattison 1980, Miller et al. 1986; Eddleman and Miller 1991; Larsen 1993), they have focused primarily on infiltration, sedimentation, interception and transpiration, rather than water yield.

Herbicide treatment of a 147-hectare pinyon/juniper stand in north-central Arizona resulted in a significant increase in annual streamflow (Baker 1984). After 8 years of follow-up monitoring, a 157% increase in annual streamflow was observed. The dead stand was removed at this time and the streamflow decreased to near pre-treatment levels (Baker 1984). Baker (1984) attributed this response to what he termed direct flow, consisting of both overland flow and interflow. This Arizona research result conflicted with studies done by Clary et al. (1974), who concluded that the potential for increasing water yield through the removal of overstory vegetation was minimal at best. Buckhouse (1984) suggested a threshold of overstory removal may exist that must be achieved in order to yield increased streamflow. In the studies in the Southwest, no significant increases in streamflow were demonstrated in areas where only a percentage of overstory was removed (Clary et al. 1974; Collings and Myrick 1966; Gifford 1973). While these studies provide conflicting results, which arguably may or may not be applicable to the western juniper woodlands, all provide insights into the complexity of this remarkable plastic and adaptable species. Currently, no literature documents paired watershed, western juniper studies on the semi-arid rangelands of the Northwest.

METHODS

The initial 8 years of this study (1994 to 2003) have been the watershed hydrology analysis and comparison of the two watersheds based on an established study area within the paired watersheds. This phase involved providing the ecological description and comparison analysis of the two study areas based on vegetation, soils, topography, geology, channel morphology, streamflow, local climate, and erosion processes. This was completed by establishing vegetation transects, channel cross-section plots, erosion plots, mapping and quantifying the topography, geology, and soils, and by the construction and installation of flumes and rain gauges. The flumes were used to acquire water yield and duration and intensity of flow. Rain gauges were installed to determine the volume, duration and intensity of precipitation.

RECONNAISSANCE

A reconnaissance process was used to provide a general coverage of the study area and to assist in the preliminary steps of the sampling procedure. The first step in this process was to stratify each watershed based on slope, elevation, and aspect. Geographical Information System (GIS) was used along with topographic maps, aerial photos, and ground-truthing to simplify the reconnaissance procedure. Global Positioning System (GPS) was also used in conjunction with GIS to locate plots, boundaries, and pertinent landmarks and to develop a project map.

The base map developed for this study was a Digital Elevation Model (DEM). The DEM was created by digitizing contour lines and other distinguishing features from a paper (hard copy) USGS 7.5-minute quadrangle map. This information was then converted to a rasterize-formatted map. This map was used as a template for the other layers of interest.

Significant features such as roads, streams, springs, and research plots were mapped using hand-held GPS units. These features were subsequently input into the system as layers in the database. This process provided the flexibility for viewing or analyzing each layer separately or as a whole.

Aerial photos were used in conjunction with GIS to assist in the vegetative sampling. This was accomplished by scanning the photos into the database. Locations were established by using GPS and by pinpricking specific locations on the photo. Ground-truthing sites were used as known points to orient (geocorrect) the photo to the already existing DEM. In GIS terminology, this process is often referred to as "rubber sheeting" (Johnson and Harris 1995). Scanned aerial photos were used to determine western juniper extent. Information derived from this process could contain substantial error. The error occurs due to spatial distortion and minimal contrast differences in tree canopy shadows and like-colored features on the photo. However, some of this error was reduced by adjusting the contrast of the photo to distinguish western juniper canopy from other like-colored objects and increasing the number of reference points.

Topographical information obtained for the study consists of aspect, slope, and elevation. Comparison of different topographic features was accomplished by classifying features into different categories. Five separate categories were used to classify aspect: north, south, east, west, and level. The "level" classification considered those areas where slope is indistinguishable, such as in ponded areas and hilltops. These five aspects were segregated and compared in the two study areas (Figure 6). Slope was also masked, compared and classified into six categories (0-20%, 20-40%, 40-60%, 60-80%, 80-100% and 100% +).

SOILS CLASSIFICATION

Soil associations were described in conjunction with Bureau of Land Management soil scientist Larry Thomas (1995). There have been no soil studies done in this specific area; thus, it was necessary to utilize reconnaissance and the agency's soils expert as the primary means of information collection. The study area was hand-mapped utilizing ground reconnaissance and aerial photos. The results of the mapping process were transferred into GIS to compare soil types between the two study areas.

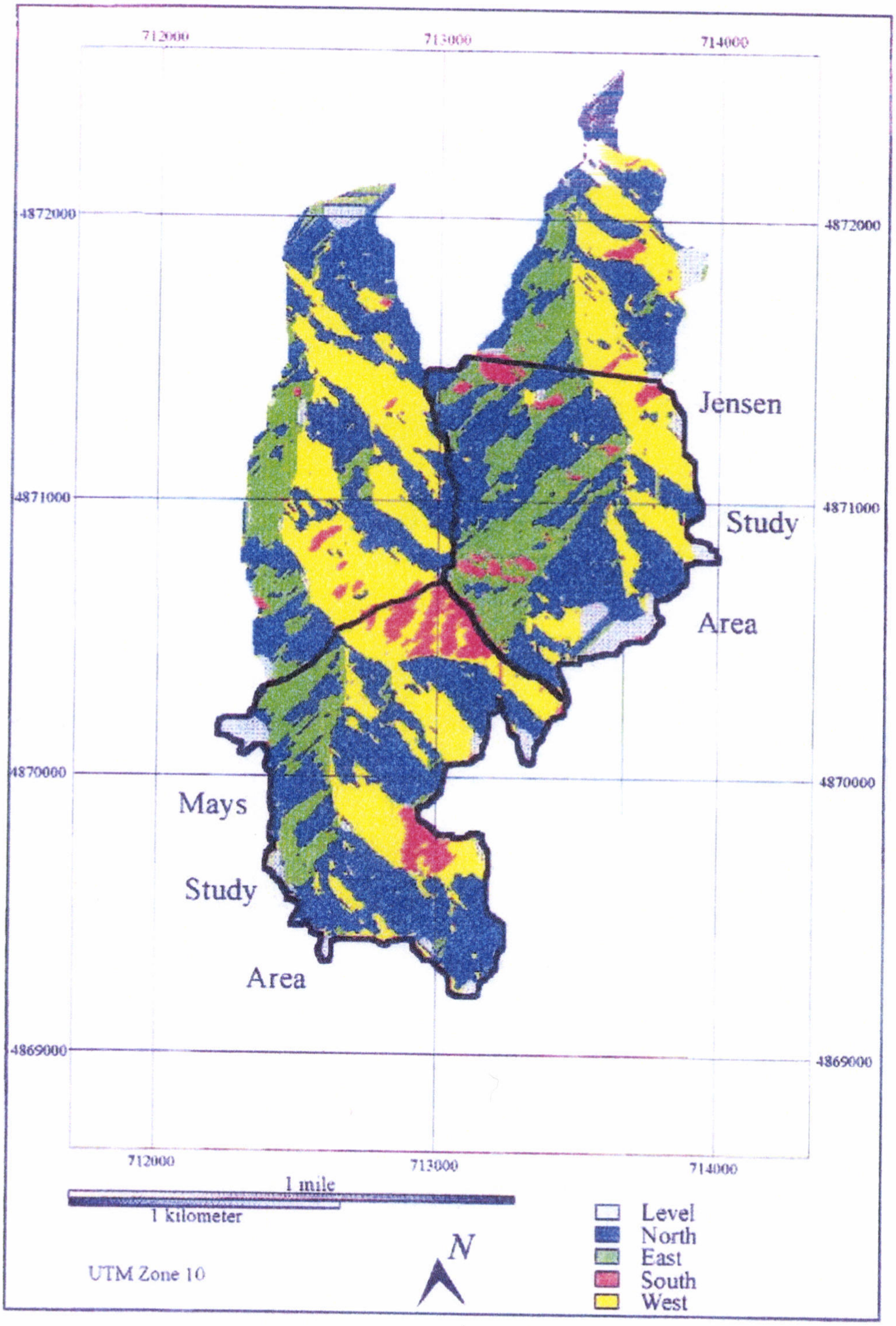


Figure 6. Study area aspect map.

VEGETATION

Vegetation measurements were obtained using standard methods, specifically, the line-intercept method (Pieper 1973). Sites were stratified by slope and aspect (north, south, east and west). Samples were randomly taken within the two strata (Appendix C1 and C2). Transects (30-meters in length) were established perpendicular to the slope with permanent markers. Transects were established and measured in 1995 and measured again in 2003.

Cover was determined using basal cover for perennial and annual grasses and foliar cover for forbs, shrubs, and trees. Bare soil was reported in terms of bare surface soil. Litter measurements included moss, needles, and woody material greater than 2 centimeters in diameter. Rock measurements were limited to rocks equal to or greater than 13-centimeters at the point of tape intercept. Species diversity was accomplished using ocular reconnaissance. Western juniper frequency and stand density measurements were obtained using aerial photos in conjunction with GIS.

PRECIPITATION

Precipitation was measured in both study areas. A Belfort Instrument Company "Universal Rain Gauge" was placed near each flume at similar elevations to measure precipitation volume, intensity, and frequency. The rain gauges were installed during the winter of 1994/1995. Measurements were collected to an accuracy of 1/20th of an inch (approximately 1 millimeter) at 6-hr interval for

30-day periods (Appendix G). Annual average precipitation data was obtained from Barnes Weather Station, Oregon Climate Service, Oregon State University.

HYDROLOGY

Channel Flow Measurements

A 3,0 H-Flume (Appendix D) was placed in the lower end of each study area to obtain an estimate of the total volume of streamflow per watershed. Location of the prefabricated flumes was dependent on channel morphology and accessibility. A fabricated-steel approach section was attached to the upper end of each flume. A flow meter (pressure transducer) and data logger were used to record and store flow measurements. Specific input on flumes and data loggers was obtained from Robert Brown (Intermountain Research Station), Clyde Best (Campbell Scientific) and Alan Belyea (Plastifab Inc.).

Flow measurements were taken starting in January 1995. The annual, winter runoff period served primarily as a calibration period to trouble-shoot potential problems of the flume system. This precipitation period also provided sufficient data to assist in determining the type of data collection program necessary for functional and efficient data logger output. Although both measuring devices were in place by mid-February of 1995, flow only occurred in Mays study area. The Mays flume and data logger recorded flow during late winter, spring and summer periods.

Flume Setup and Layout

The first step in the flume placement and selection was the reconnaissance of the area to be evaluated. This included selection of channel locations having low (2-4%) gradients, good access, and appropriate channel geometry. Flume placement was also critical, in that the study-area size was dependent on the flume location (Appendix C3 and C4).

Proper channel gradient is essential for maintaining accuracy of flume measurements (Grant 1992). For every 1% increase in slope greater than 2% gradient, there is a relative loss of accuracy of up to 5% in the stage measurement.

Proper channel geometry was emphasized in order to allow for ease of flume placement and greater flume stability. Flumes and channels were matched according to depth and width, since poor fitting requires excess soil removal and/or fill and can make the flume vulnerable to washouts.

Flume Selection

Careful selection of flume type was made. Factors considered were channel gradient, potential channel sediment load, expected duration and intensity of flows, duration of the study, and whether to use a flume or a weir.

Channel gradient can influence the degree of accuracy of the measuring device. Flumes in general tend to provide increased accuracy at higher gradients (Grant

1992), whereas weirs provide greater accuracy at low flows, but lose accuracy as flows increase.

Sediment delivery is an important factor in flume selection. A flume that fills with sediment will not provide accurate measurements. Flumes are constructed with a flat bottom that increases sediment-flushing efficiency, whereas weirs rely on an upstream stilling pond for measurements. Stilling ponds can fill in quickly when exposed to high sediment loads and provide little if any flushing action (Grant 1992).

Projected intensity and duration of flow influence the size of the measuring device selected. Smaller flumes can provide a high degree of accuracy at low flows but can also wash out during high flow events. Oversized flumes have good accuracy for high intensity events, but have low accuracy at lower intensity flows (Grant 1992).

Given the above, the 3,0 H-flume was selected. This style and size of flume allowed for measurements at very low flows, such as 0.028 liters per second. These flumes can also function during more intense flows of up to 566 liters per second. It also provided for higher accuracy associated with weirs, as well as the sediment flushing capability of the traditional flume (Grant 1992). The fiberglass construction of the selected H-flume provided durability, increased longevity, and ease of placement.

Flume-approach

A flume-approach produces a calming effect on the water before it reaches the flume. The approach used in the study had a diameter (1.22 meters) and height (1.07

meters) equal to that of the flume (Appendix F). A minimum length of 2.74 meters was established to decrease the potential for error that could occur as a result of excessive turbulence.

Both approaches were custom-fabricated from 16-gauge galvanized steel. This proved both cost effective and provided for ease of installation and the structural integrity necessary for a long-term study. Other approach materials considered included concrete, marine-grade plywood, natural materials (soil), and prefabricated fiberglass. These alternative materials were cost-prohibitive and lacked ease of installation or long-term structural integrity.

Data logger and Flow Measuring Device

The two data loggers (Campbell Scientific CR10's) were used in conjunction with the flume apparatus. The following were considered in choosing the data loggers:

- -Ease of use
- -Proficiency of product
- -Adaptability to multiple measurement devices
- -Durability
- -Cost of product and accessories
- -Customer support
- -Product warranty

The CR10's best met the above criteria. The Campbell Scientific PC208© software was used in the data managing of the CR10's. This software allowed for user-friendly programming and data collection (Appendix E). This program was used to collect temporary stage measurements every 10 seconds. After 10-minute intervals, minimum, maximum, and average stage measurements were sent to final storage if head equaled or exceeded the set parameter of 0.05 inches (1.27 millimeter). This limited the collection of "zero" data readings that can fill a database rather quickly. Time of day, Julian day, and year were recorded as well as a 24-hour average, minimum, and maximum stage measurement, as required.

A Druck© pressure transducer was used to obtain the actual stage measurements. This transducer provided differences in pressure corresponding to different levels of stage. The pressure transducer also requires placement in a stilling well (Appendix D).

The stilling well was attached to the main flow channel by a small inlet pipe. Its purpose was to buffer the measuring device from data surges that can be caused by wind or high velocity flows (Grant 1992). The stilling well consisted of a vertical piece of PVC pipe (15.2-centimeter diameter by 122 centimeter deep) as the chamber and a 3.8-centimeter inlet pipe located near the flume throat. The stilling well was filled with a biodegradable anti-freeze, mineral oil, and water mixture. The anti-freeze and mineral oil were necessary to prevent freezing and evaporation.

The pressure transducer was immersed in the liquid 61 centimeters below the water line equal to the flume floor and 31 centimeters from the stilling well bottom (Appendix E). The transducer was positioned in the stilling well off the well bottom to avoid sediment accumulation and deep enough in the well to buffer any noise (waves) that might have occurred during high flows. A 15-centimeter deep sediment catch was installed in the hole in the flume body was covered with wire screen (0.6-centimeter mesh) to prevent passage of large material into the stilling well.

EROSIONAL PROCESSES

Main Channel Processes

The intent of the channel cross-sectional plot (Figure 7) was to provide a morphological description of the primary channels and a means of estimating water flow at 30-meter intervals along each channel using the estimated active channel area. The morphological description is in place and provides an opportunity for comparison of channel structure changes on a biennial basis. Using cross-section measurements to estimate discharge requires actual channel flow measurements at the location of the flume. The flume discharge

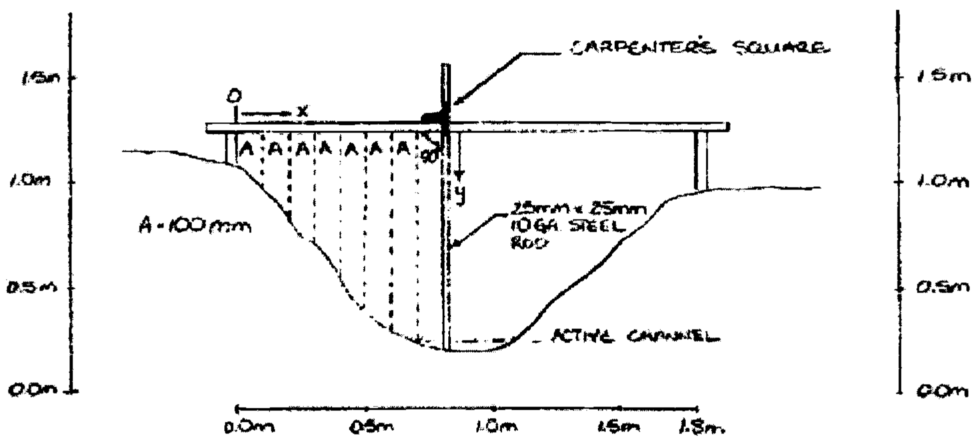


Figure 7. Diagram of cross-section plot layout.

measurements can be used in conjunction with estimated active channel area to extrapolate flow at the point of the cross-sectional plot.

Channel cross-section plots (25 per study area) were installed in the primary channels at 30-meter increments starting at a random point above the flume locations (Appendix C5 and C6). Permanent stakes were set on both sides of the channel to mark the location of each cross-section. A stationary steel tube (25 mm^2) was used to measure relative width and depth of the channel at 100-millimeter increments between the stakes. Pieces of 1.22 meter and 2.44 meter angled steel were used in conjunction with a carpenter's level to level the cross-tubing (and stakes) and provide a right angle for vertical measurements. The location of the active channel in each cross section was recorded. Photos were taken both downstream and upstream at each plot. Channel gradient was recorded between each cross-sectional plot utilizing a clinometer.

Hillslope Processes

Sedimentation plots are used to determine annual or semi-annual active, sub-basin-level erosion processes. Sampling was limited to those sub-watersheds having existing rills that exhibited evidence of surface flow from the hillslope to the main channel.

Twelve sub-watersheds were selected in each study area for sedimentation measurements (Appendix C7 and C8). Three sedimentation rods were placed in each sub-watershed using a systematic, randomized approach. The first stake was randomly placed between zero and ten meters from the channel edge or adjacent trail or road. Subsequent rods were placed at 20-meter intervals. Blocking was done by sub-watershed with study area being the treatment. There were 12 repetitions within each watershed. For the purposes of this analysis, sedimentation is defined as the erosion or deposition of soil. Soil movement is defined as the absolute values of both removal and deposition of soil. Three categories were analyzed, relative to the distance from the main channel bank: 1) 0-10 meters, 2) 10-30 meters, and 3) 30-50 meters.

Sub-watershed measurements included: aspect; slope percentage between each rod; upslope and downslope rod heights; and distance to the first rod from the channel. Photos were taken of the bottoms at each sub-watershed in an upslope direction. Measurements were taken both pre-summer and post-summer (2000-2003) in order to differentiate between erosion caused by spring runoff versus erosion caused by summer storm events. Prior to the year 2000 data was collected on an annual basis.

Sedimentation plots consisted of angle iron stakes buried, with the inside of the angle facing downslope to minimize capture of debris (Figure 8). In order to account for upslope debris capture, measurements were taken from the stake top to the soil surface on both the upslope and the downslope side and averaged.

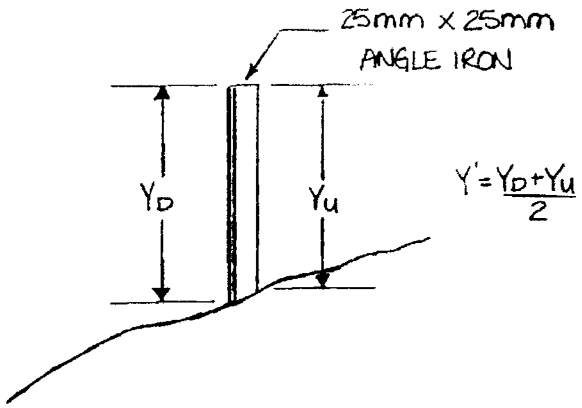


Figure 8. Diagram of sedimentation rod.

GEOMORPHOMETRY

Software

Obtaining the DEM from a website provided some initial challenges but proved a simple task once websites were located that had appropriate indicators for the DEMs being selected. This task involved locating the website, obtaining the United States Geological Service (U.S.G.S.) Logan Butte Quadrangle DEM and running the file through an unzip program where the DEM can be expanded for use in the MicroDem© software. Mays canyon and Jensen canyon watersheds were subsampled out of the Logan Butte Quadrangle for more detailed analysis.

Stratifying Area Subsamples

Obtaining area subsamples includes the simple process of identifying the areas of interest on the DEM and cutting the smaller units out of the DEM in order to create smaller DEMs. This can be accomplished through ground-truthing and/or knowing the UTM or latitude and longitude coordinates for the area of interest. Once the areas are identified, they should be amplified for easier viewing and analysis of features using the subsample function within MicroDem©. If the zoom function is utilized, the file size will grow to a level that becomes less manageable. Once the subsamples are delineated, they can be saved as an individual DEM, allowing for analysis of that specific region. The next step is to digitize streams from the two subsampled DEMs in order to obtain stream profiles (cross-sectional representation of the amount of relief present in a stream channel from top to bottom).

Digitizing Stream Channels

Stream digitizing consists of following the most prominent contour crenulations with the digitizer. Stream profile analysis is accomplished by choosing the stream profile function within the "Calculate" menu. For the purposes of this project, only the primary stream channels (stream order 2) were digitized (one per watershed). The point of origin for each profile is based on an estimation of where the bottom of each of these study areas would be. In actuality, the watersheds are broken up into study areas by the placement of flumes in the bottom of the study area.

The upper-most point of the profile was determined by stopping the digitizing at a point midway between the last prominent crenulation and the next contour line. Following the digitizing of the stream profile, the secondary stream channels (stream order 1) with moderately apparent crenulations were digitized and printed out for visual analysis of stream channel complexity. The final procedure includes the processing of elevation versus relief, constructing a statistical slope orientation (SSO) diagram (Chapman 1952), constructing perspective and oblique views of the study areas, and blue lining the topography map delineating the stream channels present in each watershed.

STATISTICAL ANALYSIS

Linear regression approach is the primary tool used in statistical analysis of paired watersheds (Eschner et al. 1966; Yue 1987; Gottfried 1991; Clausen et al. 1996; Knight 1987; Larsen 1997; Burton 1997; Mcfarlane 1998; Sharda et al. 1998; Bonta et al. 2003; Grant 2003). Although there are other tools available, such as a robust regression analysis, the linear regression appears to be the current standard throughout the literature. Statistical analyses of this study will provide a descriptive breakdown of the parameters within each watershed as well as a comparative analysis between the watersheds. The data is paired by the season of data collection on an annual and biennial basis. Most of the data sets comprise some form of missing data due to weather, equipment failure, or failure to download data prior to data overlap on dataloggers.

RESULTS

SOILS CLASSIFICATION

Descriptive soils classification (Appendix A) demonstrated there to be four primary soil series within the study area (Table 3).

Table 3. Soil series classified by percentage of total area in each watershed.

Soil series	Jensen	Mays
Westbutte	26	50
Simaton	21	3
Madeline	48	20
Embal	0	1

The data showed Westbutte soil series to be nearly twice as abundant in Mays as Jensen watershed. The Simaton series is five times more abundant in Jensen than Mays and there is twice the area of Madeline series in Jensen than Mays watershed.

VEGETATION

Data from eight, 30-meter transects were analyzed within each watershed and averaged as a whole and compared between the two watersheds (Appendix H). Data were collected in two periods, 1995 and 2003. The data were analyzed by blocking for aspect, year and watershed.

Variables describing percent canopy cover were analyzed using the analysis of variance (ANOVA) procedures of MiniTab© statistical software package. Appendix I contains the summary of the analysis of variance.

Partial results of the analysis of variance of variables describing percent canopy cover over the two collection periods, within the two watersheds, are shown in Table 4. Blocking was done by watershed. There were four replications per treatment.

Table 4. Significant P-values from ANOVA for variables describing influence of watershed on percent cover.

	Jensen	Mays	P-value
Perennial grass	14.8	10.6	0.145
Bare soil	22.9	23.9	0.585
Litter	25.6	30.1	0.962
Live shrub	4.9	5.7	0.591
Dead shrub	5.5	2.1	0.053*
Tree	21.4	26.9	0.748
Forb	2.4	2.4	1.000

*shows significant difference at Alpha = 0.05
**shows significant difference at Alpha = 0.10

There was a significant difference between the percent cover of dead shrubs between Mays and Jensen watersheds. The percent cover of dead shrubs in Mays watershed averaged 5.5% with Jensen watershed averaging 2.1%. There is not a significant difference of percent cover between watersheds of other parameters to include perennial grass, tree, and bare soil. Data were initially blocked by aspect due to the assumed effect that aspect would have on the results. Two-way ANOVA tests for interaction of aspect on watershed and years showed no interaction effect (p-value > 0.05).

There is evidence that aspect influences the percent cover of perennial grasses and forbs (p-value of 0.005 and 0.045 respectively) when controlling for watershed and/or year. Under these study conditions, aspect effect did not express itself for tree, live shrub, dead shrub, litter, or bare soil (table 5).

Table 5. Significant P-values from ANOVA for variables describing influence of aspect on percent cover.

	North	South	East	West	P-value
Perennial grass	16.4	8.1	12.1	14.2	0.097**
Bare soil	27.2	26.7	20.4	19.4	0.586
Litter	21.4	32.6	30.8	28.1	0.817
Live shrub	5.6	2.9	4.1	8.6	0.174
Dead shrub	4.9	3.0	2.5	4.8	0.354
Tree	18.0	37.5	15.9	25.2	0.443
Forb	5.1	0.1	1.5	3.0	0.005*

*shows significant difference at Alpha = 0.05
**shows significant difference at Alpha = 0.10

Based on DEM analysis using GIS, estimated frequency of western juniper was 45% (135 out of 330 sampling points) in Jensen and 41% (197 out of 483 sampling points). Western juniper density was estimated to be 743 trees/ha and 680 trees/ha in Jensen and Mays watershed respectively. Western juniper density was observed to be greatest in the drainage bottoms and lower slope positions.

PRECIPITATION

A strong linear relationship exists between the two watersheds relative to precipitation input ($r^2 = 0.9801$). The data (Figure 9) illustrates that for every 1 centimeter of precipitation that falls in Jensen there will be approximately 0.92 centimeters falling in the Mays watershed. Average annual precipitation over the study period was 270 millimeters.

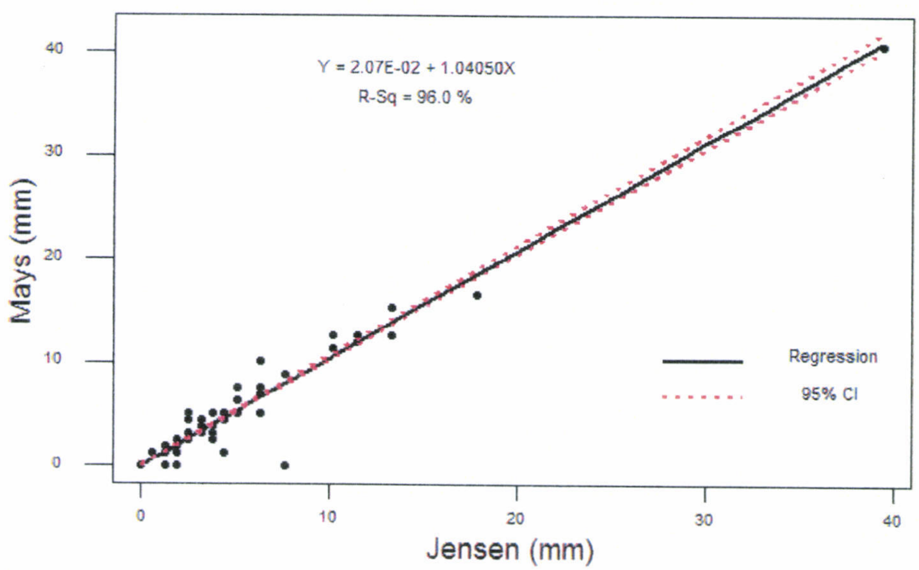


Figure 10. Regression graph of an example of the comparison between Mays and Jensen daily average precipitation in millimeters for the year 1998.

HYDROLOGY

Channel flow proved to be a challenging parameter to quantify. There are multiple possibilities for analyzing the data, ranging from hourly discharge to annual, cumulative volumes. I chose to attempt several of these methodologies with the idea of obtaining the best predictive relationship for the objectives at hand. I determined it made most sense to observe the spring runoff events as daily and/or monthly averages and the high intensity summer thunderstorm-driven events on 10-minute maximum flow (Appendix M). To compare watersheds on a long-term basis, cumulative volume proved to be an amiable approach. Regression analysis was applied to all combinations of data, and no relationship was found. Table 6 shows a comparison between the two watersheds using estimated total annual volume.

Table 6. Estimated annual cumulative volume in cubic feet and acre feet based on flume measurements.

	Jensen		Mays	
Year	(cf)	Acre feet	(cf)	Acre feet
1995	0	0	5,041,394	115.7
1996	479,263	11.0	1,077,802	24.7
1997	537,889	12.3	1,114,961	25.6
1998	174,389	4.0	186,620	4.3
1999	1,484,827	34.1	745,249	17.0
2000	0	0	238,323	5.5
2001	0	0	2,937	0.07
2002	20,753	0.5	96,996	2.2
2003	0	0	0	0

Mays watershed produced water volume nine out of 10 of the data collection periods, whereas Jensen watershed did not produce flow for the years 1995, 2000, 2001 and 2003. Mays watershed also produced more than twice the volume of Jensen watershed for three out of the 5 years that both watersheds produced volume. The 1998 data shows Jensen and Mays total volumes to be within 6% of one another with totals of 174,389 ft.^{3} and 186,620 ft.^{3} in Jensen and Mays respectively. Water data during the 1999 season is an exception in that Jensen produced a total volume of 1,484,827 ft.^{3}, compared with a total volume of 745,249 ft.^{3} in Mays watershed.

In contrast, Figure 10 shows a comparison using average annual flow in cubic feet per second (cfs).

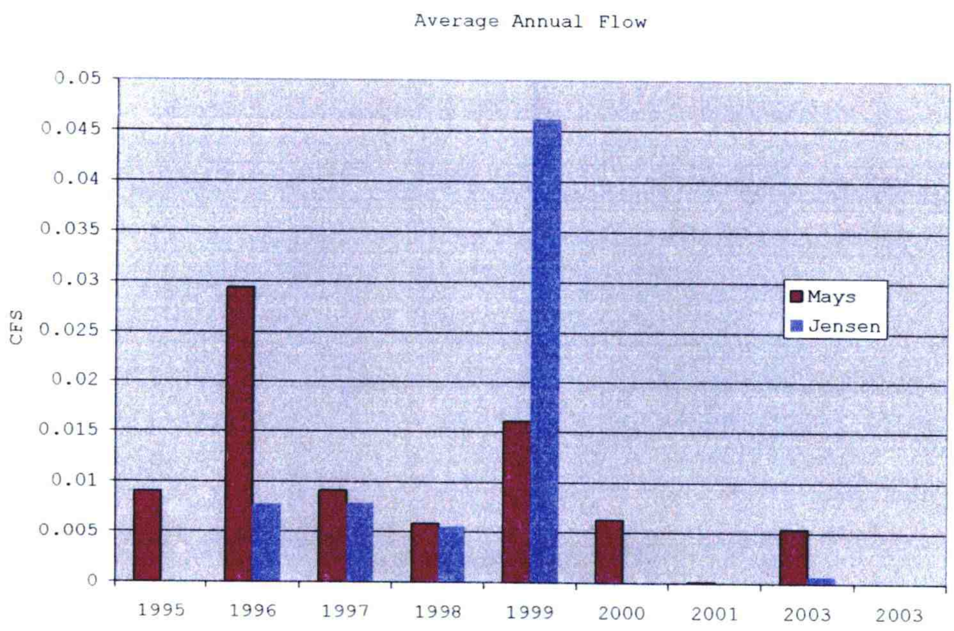


Figure 10. Comparison of average annual flow in cubic feet per second from 1995 thru 2003.

Comparison of the total amount of volume produced during 1996 calendar year is displayed in Figure 11 as an example of cumulative flow on a daily basis. Assuming similar precipitation inputs, there is double the amount of surface channel flow at the flume location in Mays as compared with Jensen watershed during a spring runoff period.

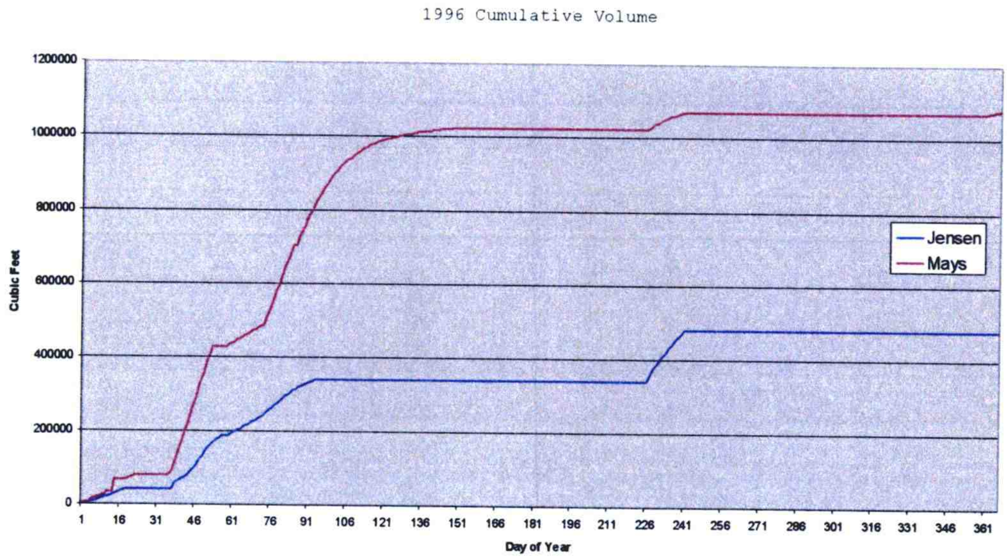
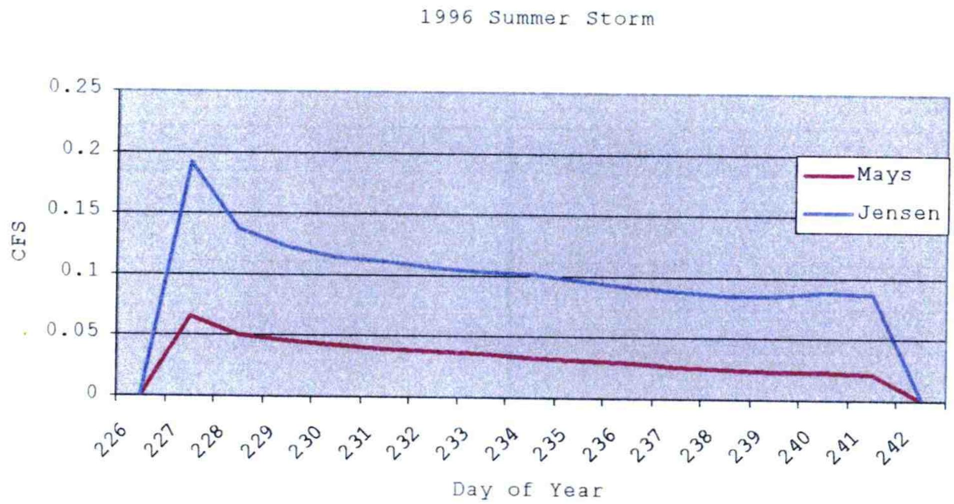


Figure 11. Hydrograph showing comparison of cumulative average volumes during 1996 season including both spring runoff and summer thunderstorm.

The August 1996 summer thunderstorm event showed the alternative to be true. This event, when graphed on a cumulative basis using daily averages shows Jensen watershed to have a shorter but larger response. When looking at the same storm event using daily maximum flows, the data shows a very similar pattern of rise and fall of discharge and response time (Figure 12).



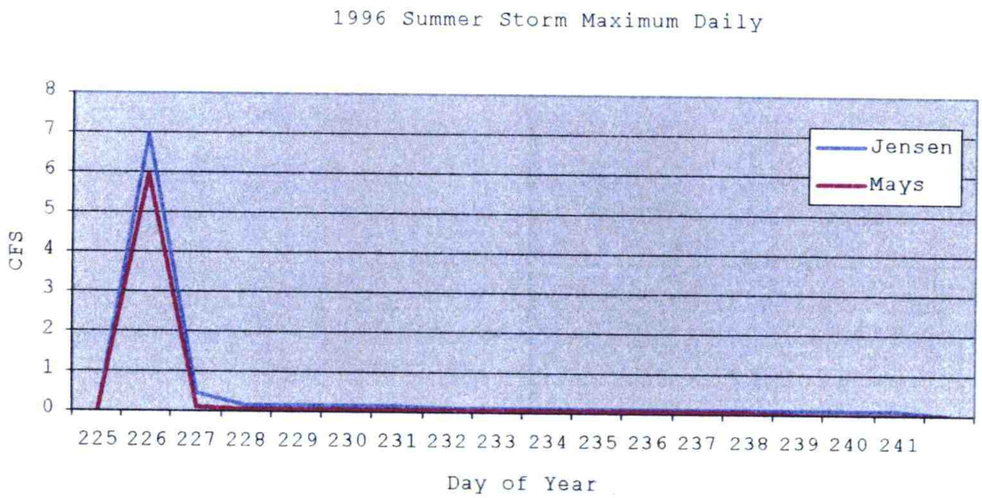


Figure 12. Hydrographs showing comparison of daily averages and daily maximum discharge of 1996 summer thunderstorm.

The 10-minute maximum flow of the event continued to demonstrate this pattern, but picked up the more intricate flow responses to include the second rise in the hydrograph, occurring 1.5 hours following the first (Figure 13). The actual magnitude of this type of event could have very likely been as much a product of the location of the storm event as the hydrologic characteristics of the watershed. What it did illustrate was how quickly the system is capable of obtaining high surface flows and subsequently releasing them quickly.

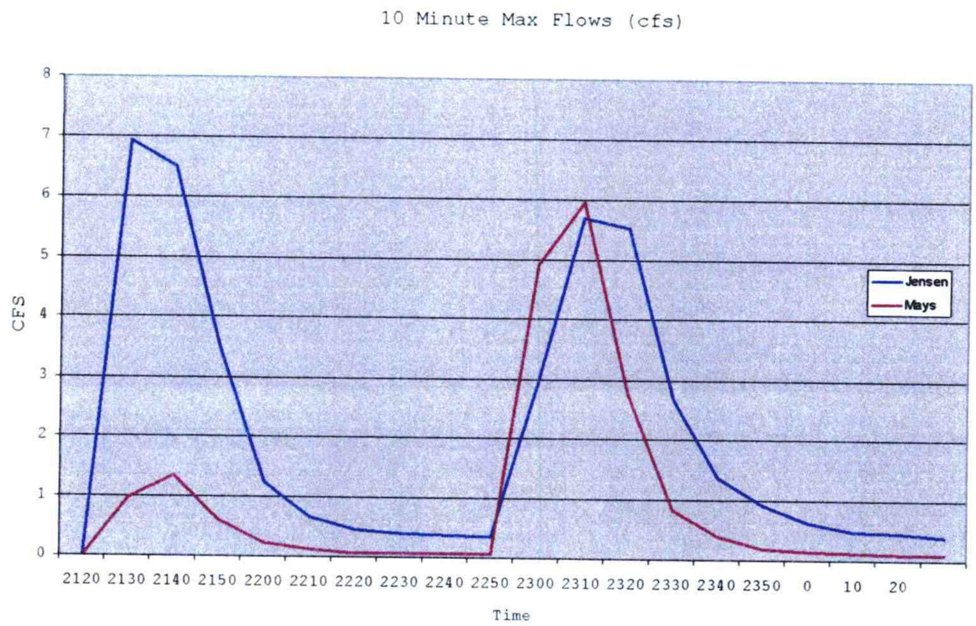


Figure 13. Maximum channel 10-minute interval discharge from 1996 summer thunderstorm.

MAIN CHANNEL EROSION PROCESSES

Data was compiled using Reference Reach software© provided by Dan Mecklenburg, Ecological Engineer Ohio Department of Natural Resources, Division of Soil and Water Conservation. This software allowed graphical representation of cross-section data (Appendix J) while providing numerical output of parameters such as total cross-section area, deposition, and scour (Appendix K). Data were analyzed based on these three processes.

Cross-section area was defined as the total area in square centimeters within the cross-section plot. The top of the area measurement was defined by the highest point on the cross-section plot. The cross-section area measurement consists of a combination of the scour and deposition measurements. The deposition measurement consisted of area in the cross-section plot in square centimeters that received an increase in channel material at that location. Scour values are the opposite of deposition and defined as a loss of channel material in square centimeters at the cross-section plot location. Additionally, this software provided an approach for comparison between the two watersheds by comparing the differences from one data collection segment to the same parameter of the data collection segment preceding it. These differences were compared using Minitab© statistical software producing the summary statistics found in Appendix L.

The data collection period was from 1994-2003, consisting of 12 repeated measures. Data for the periods of 7/25/2000-1/7/2000 and 12/23/2002-8/19/2003 did not provide comparisons between watersheds due to unavailable data for the Mays watershed. Data was analyzed in two ways: The first analysis compared the two watersheds based on summing the changes over time of each cross-section and comparing the 25 sums between the two watersheds. The second approach consisted of averaging the changes in the 25 cross-section plots for each of the 10 collection periods. The comparison was then applied to the 10 average values for each watershed. The first approach alleviated the concern of auto correlation occurring between the time series data. The second approach involved the risk of auto correlation but gave a good representation of changes over time. Both approaches have merit, but since collection periods covered differing intervals, each (especially the second) must be viewed in context. The regression analysis of the cross-section data used the second approach of comparing the two watersheds based on averages over time.

Area

Table 7 data indicated cross-sectional area was significantly different between the two watersheds when comparing the sum of changes over time (first method) (p-values = 0.002). The average of the sum of changes over time of the cross-sectional area was -2577cm^2 and -5422cm^2 for Jensen and Mays respectively.

Table 7. Cross-sectional area statistics in cm^2.

	Sum over Time	P-value(2-tailed)
Jensen	**-2577**	
Mays	-5432	
		**0.002

**shows significant difference at Alpha = 0.05
*shows significant difference at Alpha = 0.10

Channel cross-sectional area did not appear to change dramatically between collection periods except for the periods of 1994-1996 and 2000-2001 (Figure 14).

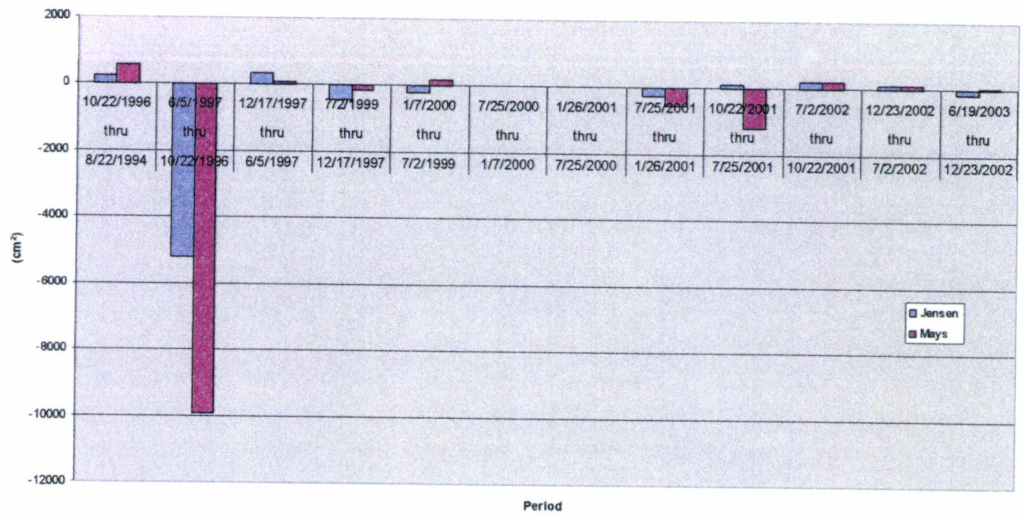
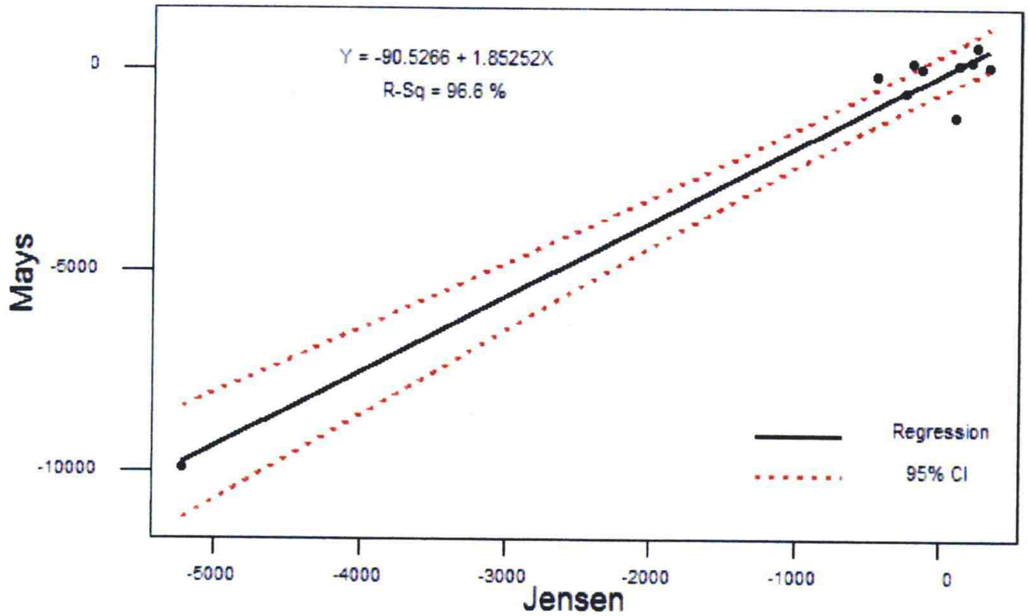


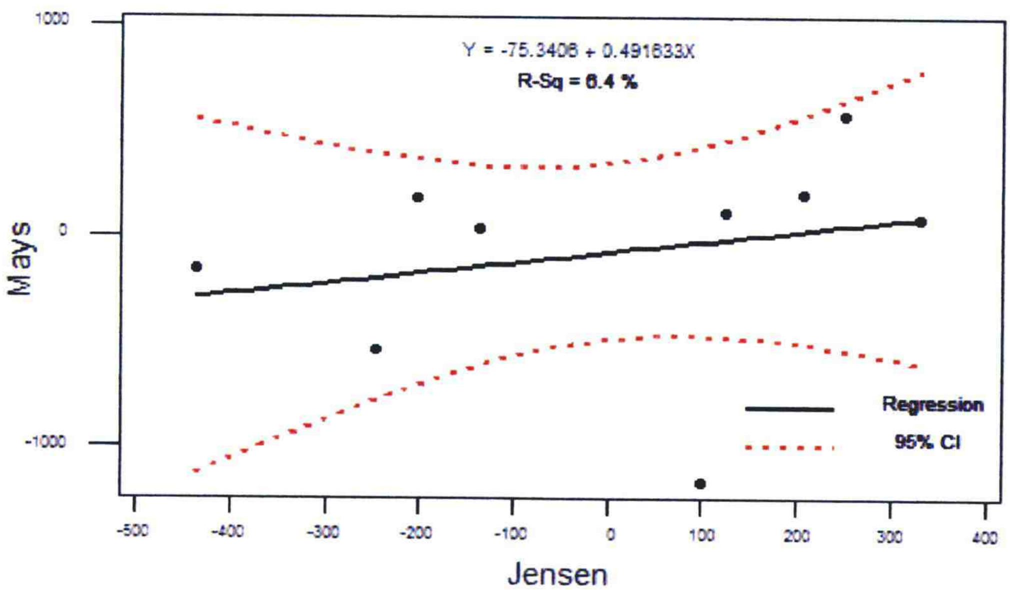
Figure 14. Changes in cross-sectional area between collection periods in cm^2.

The largest difference occurred during the winter of 1996. This change in area was represented primarily by loss (scour) of channel material as will be discussed later. Spring of 1997 and 2001 showed a dramatic decrease of cross-sectional area in both watersheds (in 1997 in particular), whereas summer of 2001 showed a decrease of the cross-sectional area in Mays watershed and only a slight change in cross-sectional area in Jensen represented by a positive change. For successive sample periods a decrease in area was representative of channel deposition or aggregation whereas an increasing value in area was representative of scour or channel degradation.

Regression analysis in Figure 15 demonstrated a comparison of the potential for a predictive, linear relationship with and without the outlier data of the spring of 1997 data set. The regressions were based on averaging across the 25 cross-sections and comparing these averages between the 10 different collection times. Figure 10A showed a strong linear relationship between the two watersheds (r^2=0.9665). The variation in data could be adequately explained with a p-value of less than 0.05. The resulting equation suggested that for every 1cm^2 change in Jensen cross-sectional area, there would be an expected change of 1.852 cm^2 in the Mays watershed channel cross-sectional area. Figure 10B showed the same data with the outliers of the 1997 event removed. This regression showed no linear relationship supported by a high p-value. With the outliers removed, the resulting regression equation was not an adequate predictive tool.



A.



B.

Figure 15. Regression graphs of the average difference in channel cross-section area with outliers in graph A. and without outliers in graph B. Graph A shows an r^2 of 0.9665 and a best-fit line equation of y=1.8525x-90.527 (p-value = 0.027464), graph B. shows an r^2 of 0.0642 and a best-fit line equation of y=0.4916x - 75.341 (p-value = 0.511)

Deposition

Cross-sectional deposition values demonstrated a significant difference between the two watersheds when comparing the sum of changes over time (p-value = 0.020). The average of the sum of changes over time of the cross-sectional deposition was 2981cm^2 and 4279cm^2 for Jensen and Mays respectively (Table 8). When comparing the average change in deposition across the 25 cross-sections of 624cm^2 in Jensen and 881.5cm^2 in Mays, there was no significant difference (p-value = 0.265).

Table 8. Cross-sectional deposition statistics in cm^2.

	Sum over Time	P-value(2-tailed)
Jensen	**2981**	
Mays	4279	
-		**0.020

*shows significant difference at Alpha = 0.05
**shows significant difference at Alpha = 0.10

The data suggested channel aggradation to occur at the rate of approximately 624 cm^2/data collection period for Jensen and 881.5 cm^2/data collection period in Mays. Conversely, the data also suggested that over a 9-year period (1994-2003), Jensen channel had aggraded by 2981 cm^2/per plot and Mays channel had aggraded by 4297 cm^2/plot.

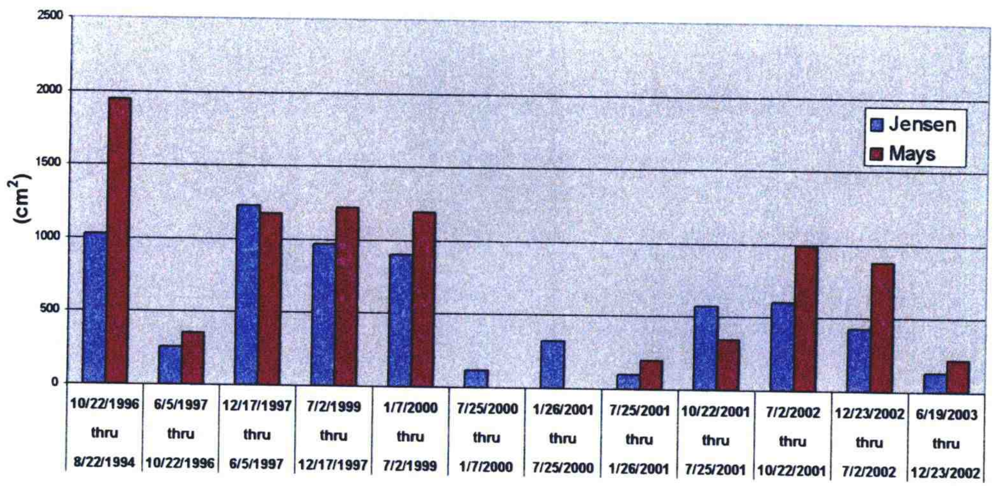


Figure 16. Change in cross-section deposition between collection periods in cm^2.

Figure 16 showed Mays watershed to consistently tend towards greater channel deposition across all collection periods except for the spring periods of 1997 and 2001. Figure 17 displayed a moderately strong linear relationship between the two watersheds ($r^2 = 0.706$) when compared across periods of data collection and averaged by cross-section plot. A low p-value (p-value < 0.005) supported the suggestion of using the regression equation developed by this data. Based on Figure 17 Mays watershed main channel should have 1.25 cm^2 more deposition action than Jensen watershed.

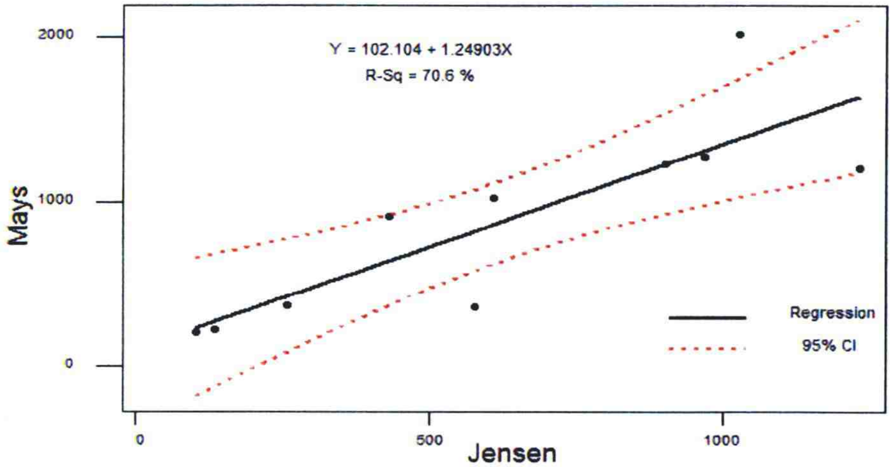


Figure 19. Regression graph of average differences in channel cross-section deposition. The best-fit line equation is y = 102 + 1.25 x with an r^2 of 0.706 and p-value of 0.002.

Scour

Cross-sectional scour values demonstrated a significant difference between the two watersheds when comparing the sum of changes over time (p-values = 0.001). The average of the sum of changes over time of the cross-sectional scour was 5558cm^2 and 9522cm^2 for Jensen and Mays respectively (Table 9).

Table 11. Cross-sectional scour statistics in cm^2.

	Sum over Time	P-value(2-tailed)
Jensen	11,636	
Mays	19,913	
		*0.000

*shows significant difference at Alpha = 0.05
**shows significant difference at Alpha = 0.10

Mays and Jensen were compared across time and averaged across the 25 cross-sections, values of 1147cm^2 in Jensen and 1963cm^2 in Mays demonstrated no significant difference (p-value = 0.458). The data showed Mays watershed to consistently have higher scour values for most collection periods except for spring of 1997 and summer of 2003 (Figure 18).

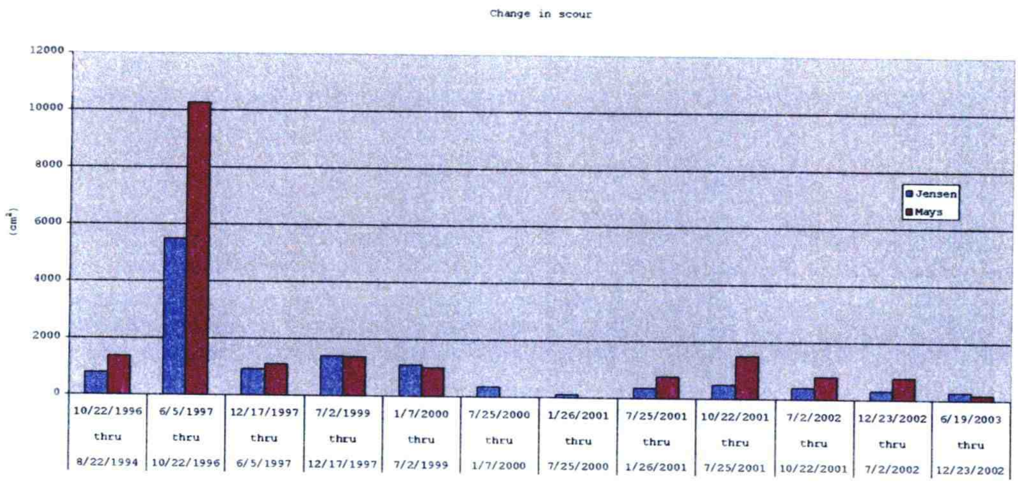


Figure 18. Changes in cross-section scour between collection periods, in cm^2.

Winter of 1996 particularly illustrated an increase in scour in Mays watershed relative to Jensen watershed. The data showed both watersheds to have lost substantial material during this period. A less dramatic, but substantial difference occurred during the summer of 2001. During this period Mays channel lost greater than three times the amount of material compared to Jensen. Examination of the raw data showed the abundance of this scour to have taken place in a single cross-section (plot

#4). The scour appears to be the product of an intense summer thunderstorm that appears to have centered more over Mays than Jensen watershed. More specifically, it appears that the thunderstorm was specific to the mid-elevation of the Mays watershed.

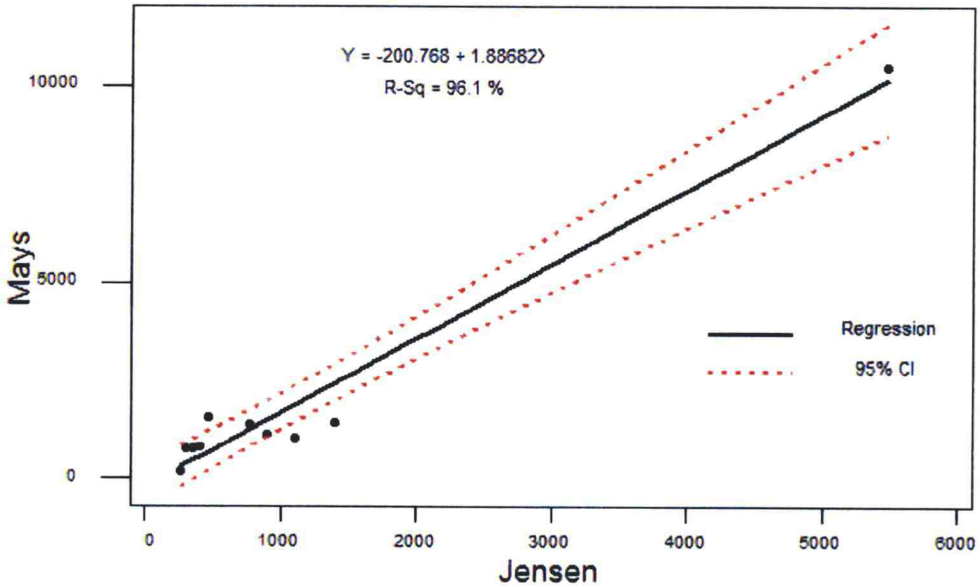


Figure 21. Regression graph of average differences in channel cross-section scour across collection times. The associated best-fit line equation is y = 1.8868x - 200.77 with an r^2 of 0.9614 and p-value of 0.000.

Regression equation output from Figure 19 indicated a strong linear relationship between the two watersheds with regards to variation in differences of scour data ($p<0.05$). This regression model also illustrated that for every 1 cm^2 in soil that is scoured in Jensen that there was 1.9 cm^2 of soil scoured out in the main channel of the Mays watershed main channel.

HILLSLOPE EROSION PROCESSES

Hillslope erosion processes (soil movement) were analyzed by taking averages of the differences between each season of data collection for the three sediment stakes of the 12 transects per watershed (Appendix N). The averages were then used as a parameter to compare between the two watersheds. MicroTab© analysis of variance procedures were used to describe the different parameters within the study area (Appendix O).

Data analysis demonstrated no significant difference between the hillslope erosion on the two watersheds (p-value = 0.694). Jensen watershed averaged approximately -0.258cm of soil movement compared with Mays watershed averaging -0.069cm of soil movement between 1994 and 2003.

The negative values that are most often associated with the summer/fall season represent deposition along the hillslope gullies. The positive values primarily displayed during the winter/spring season represent soil scour along the hillslope gullies. Figure 20 suggests the Jensen study area to be generally more erodible (not statistically) in the uplands compared with the Mays watershed. Upland erosion processes appeared more active in Jensen watershed for eight out of the 11 collection periods.

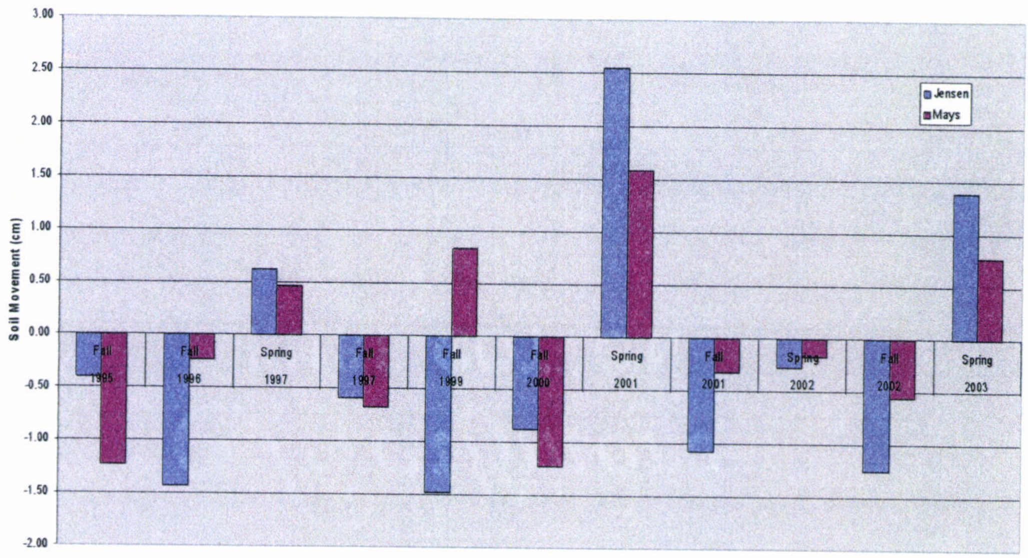


Figure 20. Comparison between watersheds of average differences in hillslope soil movement across collection periods in centimeters.

There was a weak to moderate relationship between hillslope erosion processes in Jensen and Mays watershed (r^2=0.4174). The regression equation from Figure 21 supports the previous claim that Jensen was more erodible on the hillslopes than was Mays. The data suggested that for every one centimeter of hillslope soil movement that takes place within gully systems in Jensen, there would be approximately 0.5 centimeters of soil movement in the hillslope gullies of Mays.

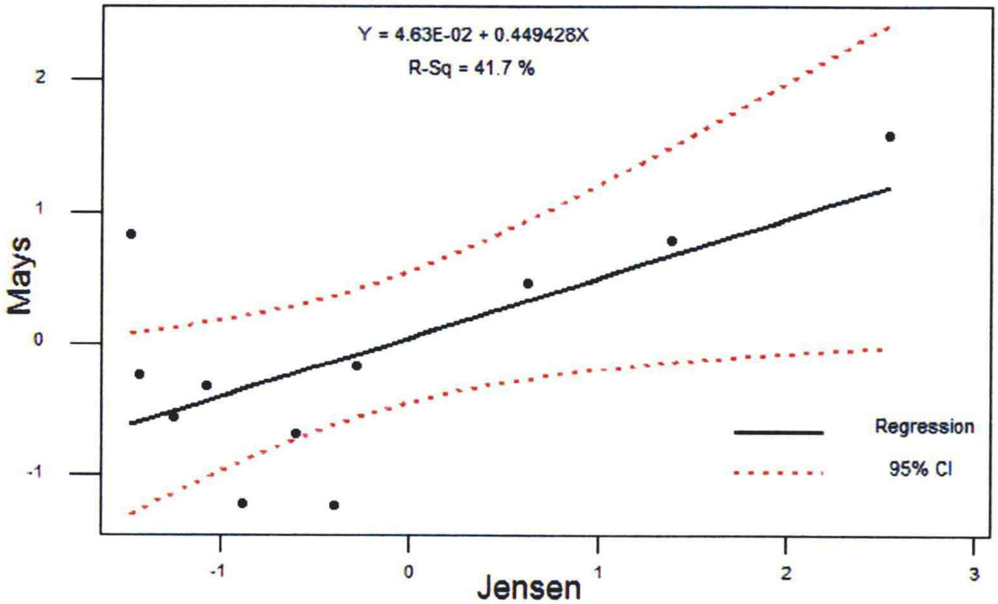


Figure 28. Regression graph of average differences in hillslope soil movement in centimeters. The best-fit line equation is y = 4.63E-2 + 0.44942x with an r^2 of 0.42 and p-value of 0.032.

GEOMORPHOMETRY

Topography

Topographical information obtained for the study consisted of aspect, slope, and elevation. These characteristics were obtained using Geographical Information Systems and supportive materials.

Average Slope

The slope characteristics differed between the two watersheds by approximately 1.6%, with Jensen watershed averaging 25% and Mays averaging 24%. The 1.6% difference in slope was minor compared with the amount of variation at 7.5% in Jensen and 7.8% in Mays.

Aspect is another very important characteristic that depicted the two watersheds to be similar in topography (Table 10).

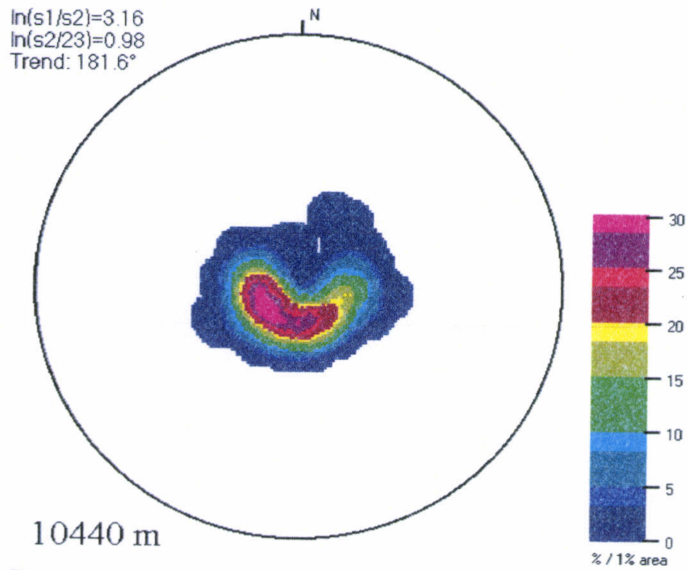
Table 10. Aspect distribution classified by percentage of total area of Jensen and Mays watersheds

Aspect	Jensen	Mays
North	36%	33%
East	31%	17%
South	5%	11%
West	23%	26%

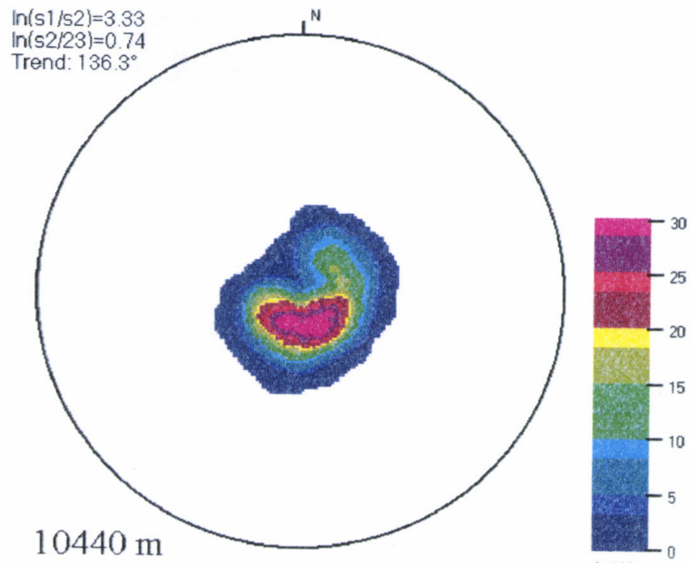
Mays watershed has approximately 10 hectares more of south-facing aspect than Jensen watershed, however, this appears to be compensated for by Jensen's 13 more hectares of east-facing aspects than Mays watershed. Both the south-and the east-facing aspects demonstrate similar qualities of dryer, harsher, extreme site characteristics.

Statistical Slope Orientation Diagrams

SSO diagrams are another method of depicting the orientation of slopes within a study area. This type of analysis can also provide previously referred to data such as flatness and organization of the topography. An SSO analysis of the two watersheds showed Jensen watershed to be primarily oriented in a northerly direction. In comparison, Mays watershed is strongly oriented in a north/northwest direction (Figure 22). The overall orientation of a northerly direction should lend both study areas to a greater duration of frigid soils and/or maintenance of a snow pack during the spring melt. This has proven to be the case when observing like-sized drainages in the same region that have an orientation in a southerly direction. Both basins exhibit frost-induced features, including stone stripes, solifluction lobes and frost-shattered bedrock outcrops, attesting to the significance of slope orientation in these basins. Frozen soils often limit snowmelt infiltration and increase runoff during the spring thaw period.



Jensen



Mays

Figure 22. SSO Diagrams of Jensen and Mays watersheds.

Flatness

Based on the values for flatness (basically defined as the degree of relief present) produced in the SSO diagram process, Mays watershed appears to be flatter than Jensen watershed with flatness values of 3.33 and 3.16 respectively.
The slight difference in flatness may partially account for the tendency toward greater hillslope erodibility in Jensen watershed as compared to Mays.

Organization

Organization can be defined as the strength of the terrain fabric (Guth 2001). In other words, the organization can determine whether the topography has a pattern of orientation such as most ridgetops following a certain aspect and/or being somewhat uniform in their relative position to one another. Organization is a low value for both study areas at 0.94 for Jensen and 0.68 for Mays. These values again illustrate that the terrain within the study is relatively flat. In comparison to areas with a higher organization number, the study area should have decreased infiltration rates. The lower organization number for Mays may explain the longer time of concentration for overland runoff, which translates into the longer 'declining limb' (tail) of the Mays hydrograph.

Perspective View

The perspective function of MicroDem provides a unique opportunity to view the watersheds in near threedimensional format and control the degree of contrast. This can be useful in identifying questionable topographical differences and for general insight into the topographic layout of the landscape. Figure 23 also demonstrated that by changing the vertical exaggeration of the image, the interpretation could be swayed. In Figure 23, the Mays image was exaggerated by two as compared to an exaggeration of one on the Jensen image. The output gives the appearance that Mays is substantially steeper than Jensen.

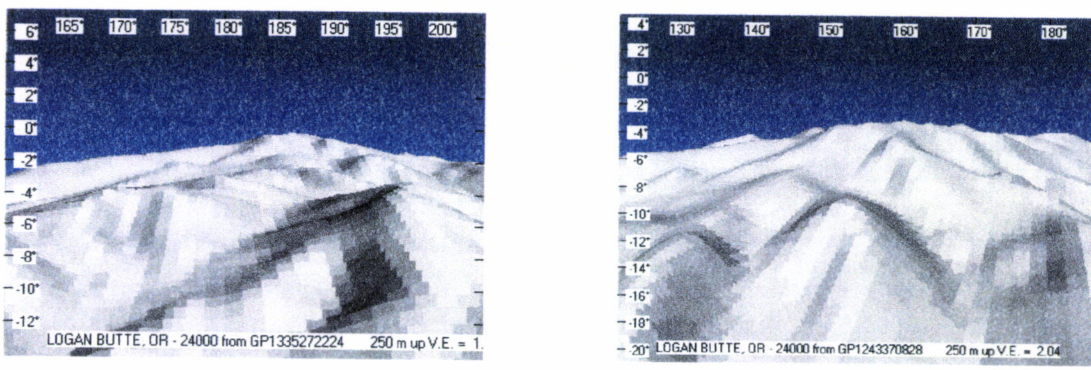


Figure 23. Jensen and Mays watersheds in perspective view, looking in a southerly direction. (Note: Mays caption illustration expanded by two)

Oblique View

The oblique view of the study areas is another way to have a visual interpretation of the amount of relief present in the landscape (Figure 24). Based on this approach, it appeared that Jensen watershed exhibits a greater percentage of bottomland or flat ground as compared with Mays. According to the slope and elevation analysis, this is not the case. This analysis showed Jensen to have approximately 8% of the total study area in slopes less than 16% whereas Mays has approximately 16% of its total area comprised of slopes less than 16%.

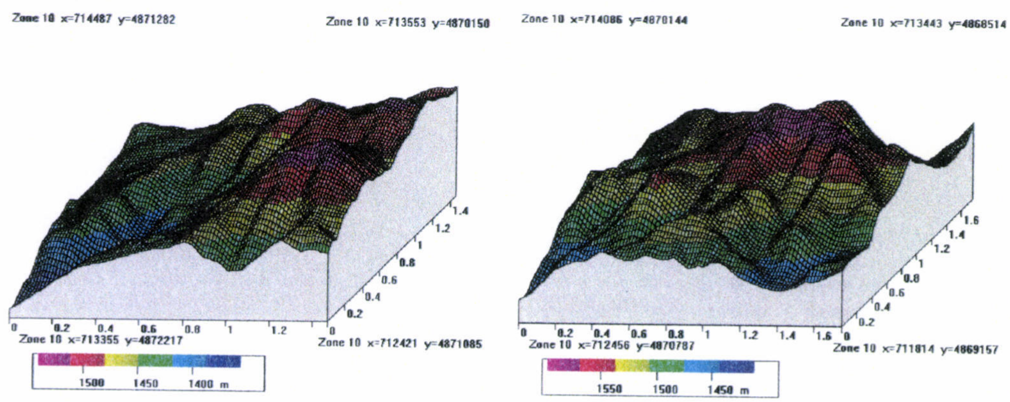


Figure 24. Oblique views of Jensen and Mays study areas.

Hypsometric Analysis

The hypsometric analysis demonstrated the two watersheds to be of similar stage of erosional development. This was characterized in the inverted s-curves of Figure 25. If one of the watersheds were substantially different in its relative developmental stage, there would be an obvious difference in the shape of the curve. A younger stage watershed would have a more convex shape to the midpoint of the curve, indicating a drainage area with steeper slopes draining sharply to a channel area with a narrow floodplain.

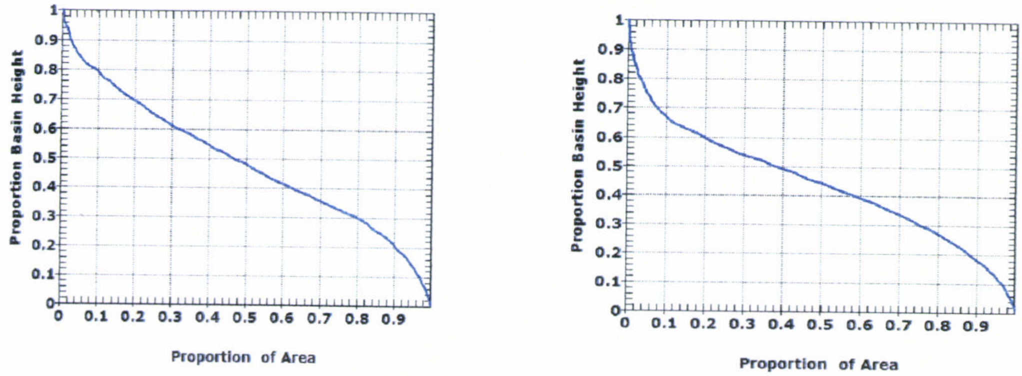


Figure 25. Graphical representation of the relative relief compared with the area encompassed by that relief in Jensen and Mays respectively.

Figure 26 showed a similar pattern of relative age of the two watersheds but gives further insight as to the area of an actual elevation. This figure illustrated Mays watershed to have increased relief in the upper elevations as well as the drainage bottoms. It shows a minimal area represented by any one elevation moving from 1430 meters to 1475 meters.

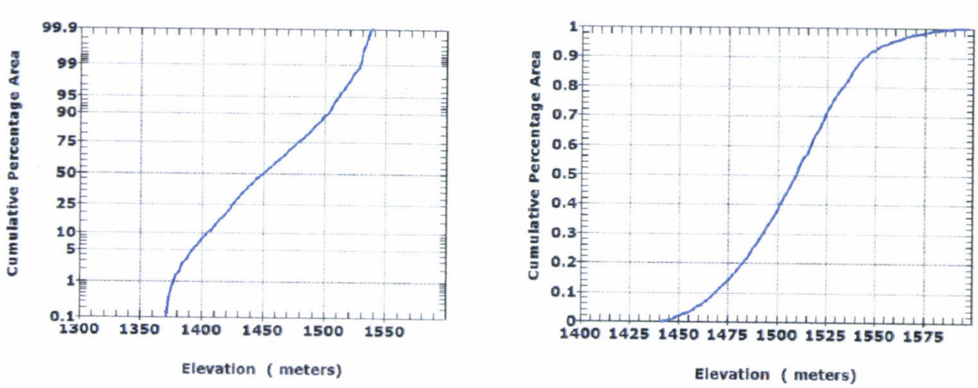


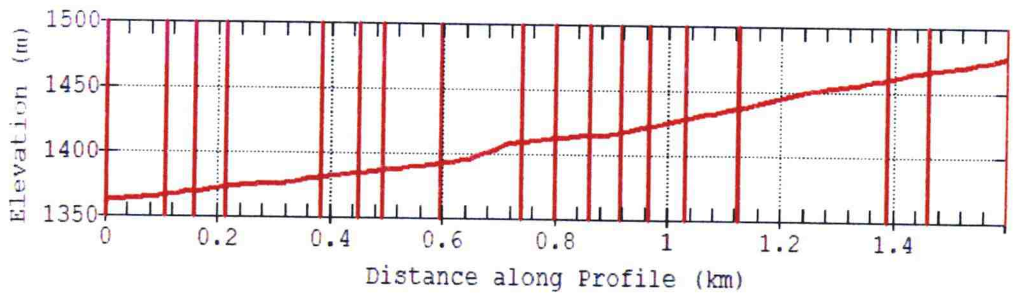
Figure 26. Graphs showing the cumulative percentage area encompassed by each elevation of Jensen and Mays watersheds.

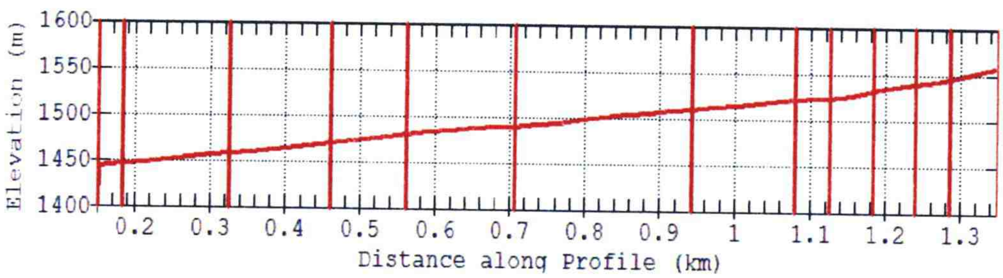
The upper end of the Mays watershed curve in Figure 26 also demonstrated a high degree of relief on the ridgetops as compared to Jensen watershed that shows each upper elevation band to contain larger areas, indicative of lower relief. These characteristics could lead to a decreased lag time for discharge from the Mays watershed as compared with the Jensen watershed. The lesser gradient at the mid-point of the hypsometric curve of the Mays watershed reflects the higher percentage of the basin area below 16% gradient, with a tendency for rill incision near the upper divide and sufficient gradient to transport sediment near the mouth, indicated by the steepness of the upper and lower ends of the curve.

Stream Profile

Stream profiles provided a useful means of determining the ability of the watersheds to transport water and other material out of the drainage area once the water is within the main channel of the drainage. Figure 27 graphically illustrates the profiles of the primary channels from Jensen and Mays watersheds. Both watersheds have primary stream channels representing similar drops in elevation of approximately 115 meters along a run of just over 1 kilometer. Also evidenced in the profile analysis is the greater length of channel of less relief in the Jensen channel versus the Mays channel. This would support the cross-section data showing an increase in deposition in the lower portion of the Jensen cross-sections as compared with Mays. It would also support the previous claim of the Mays channel maintaining stronger scour characteristics during the data collection period, due to its more-uniform drop in elevation throughout the channel length. These observations are consistent with data presented by the hypsometric curves.

A.





B.

Figure 27. Stream profiles of Jensen watershed (A) and Mays watershed (B).

Stream Order

Stream orders can be determined and used as a method of determining the complexity of a given watershed (Gregory and Walling 1973). Table 11 demonstrated the comparison of stream orders of Jensen watershed and Mays watershed. Stream orders were determined using the system advocated by Strahler (1957). This data can be used in conjunction with watershed dimensions such as width, length, and area as well as stream order length to determine the complexity of the drainage basins. Although Jensen had a greater number of stream order #2's, Mays watershed had more of stream order #1. This comparison may be of little consequence except that Mays also had twice the number of stream order #3's, which could account for a reasonable increase in flow. By Mays watershed having had an overall greater number of channel segments, channel erosion potential should have been higher in this watershed than in Jensen. An increased number of lower order stream channels will also lead to a decrease in the time it takes the runoff to reach the lower elevation segments of the drainage network.

Table 11. Frequency of stream order by watershed.

Stream Order	Jensen	Mays
#1	47	54
#2	14	9
#3	2	4
#4	1	1

This lag time in hydrologic response can account for the longer-tailed hydrographs commonly associated with Mays rather than Jensen.

The bifurcation ratio is a term used to compare the number of one order of stream channels to the next lower order (Horton 1945). In other words, the bifurcation ratio is a way of establishing a number to represent the branching or bifurcation of the drainage network. Table 11 showed the comparison of the ratios between the two watersheds. Mays watershed has nearly double the ratio of 1st order channels to 2nd order channels when compared with Jensen watershed (6 and 3.36 respectively), alternatively, Jensen has more than double Mays when comparing the 2nd to 3rd order ratio (7 and 2.24 respectively). According to Gregory and Walling (1973), values between 3.0 and 5.0 represent watersheds where geologic structure does not exercise a dominant influence on the drainage pattern (Table 12).

Table 12. Bifurcation ratios for Jensen and Mays.

Stream Order	Jensen	Mays
1-2	3:1	6:1
2-3	7:1	2:1
3-4	2:1	4:1
Weighted mean ratio	5:1	6:1

The weighted, mean bifurcation ratios of 5.05 and 6.28 for Jensen and Mays respectively, suggested that drainage patterns of both Mays and Jensen watershed are a result of limited geologic influence. These values suggest that either precipitation, infiltration-capacity of the soil or terrain and vegetative features, had a greater influence on the forming of the drainage pattern than geologic influence.

DISCUSSION

SOILS CLASSIFICATION

The soils classification showed Jensen watershed to contain a higher percentage of the more erodible, Simaton soil series than Mays watershed. The soils classification map (Appendix A) also shows the Madeline soil series to make up a large portion of the upper area of the Jensen watershed. In contrast, Mays watershed is comprised of a high percentage of the West Butte soil series that is a north slope associated soil series and less prone to erosion.

VEGETATION

Mays and Jensen watersheds have similar from a standpoint of vegetation. The vegetation plots, GIS analysis, and general ground reconnaissance support this hypothesis. Stratification by aspect did not provide the expected results; it was expected there would be some large differences in percent cover between the north and south slopes. While there are slight numerical differences, the differences were not statistical. Probably, these unexpected results can be accounted for in the sampling design of the vegetation transects. In general, transects were placed on slopes no greater than 30% and within the lower 100 meters of hillslope. Vegetative differences may be more obviously expressed when an increase in slope is combined with a change in aspect. Areas near the drainage bottom may be more influenced by the slope position than the aspect.

The three variables of most importance relative to erosion processes (perennial grass, bare soil, and tree percent cover) were not significantly different between the two watersheds.

The data showed no significant difference between the two watersheds in perennial grass, perennial forb, or tree percent cover 1995 thru 2003. From these data, it should be possible to capture any changes that may take place in these parameters following the removal of the western juniper overstory in the treatment watershed.

PRECIPITATION

The data showed Jensen to average approximately 20% more precipitation than Mays raingauge. With only one raingauge per watershed, the difference in the average precipitation amounts may be a result of raingauge location rather than actual differences in overall precipitation levels. The Mays watershed raingauge was located more in the bottom of the basin than Jensen. In addition, the Mays flume was also located in somewhat close proximity to a tree (10-15 meters). If there is a difference in precipitation, it is most likely to occur in the summer thunderstorms. These events can be extremely localized in their distribution patterns.

When comparing the study area precipitation to the Barnes weather station data, the study area averaged approximately 50 millimeters less precipitation than the weather station. This may be due to the location and an actual difference of precipitation or the type of equipment used. Regardless, the data showed the Barnes station data to be a reasonably good estimator of precipitation on the study area.

HYDROLOGY

Flow measurements were taken, starting in January 1995. The winter runoff period acted primarily as a maintenance period to determine what problems were going to occur with the flume system. This period of precipitation also provided sufficient data to aid in determining the type of data collection program necessary in the CR10 dataloggers to provide the most functional and efficient output.

When discussing the flow from the two watersheds, it would be appropriate to define the parameters of the discussion. Flow measurements only pertain to the flume location, which in turn identifies the bottom of each watershed's actual area of study. Overland flow was observed at multiple locations throughout both watersheds at times other than those periods when flow was evident in the flume. In particular, the Jensen flume location appears to have consistently missed flow events that occurred but went subsurface in the channel prior to reaching the flume location. The same was true for the Mays channel but a much larger proportion of flow surfaced in the channel at the flume location in Mays watershed. Well data showed that water was present year-round in one of the wells in Jensen. Additionally, the spring location in Mays generally produced water on a year-round basis. This demonstrates that there was water present in both watersheds that may not be recorded in the surface flow, flume measurements.

Flow intensity

On the average, Mays watershed produced greater intensity of surface flows. These occurred largely during the spring runoff period. During at least one of the summer storm-runoff events, Jensen watershed produced a higher intensity flow than Mays watershed. This August 1996 event demonstrated that Jensen has the ability to produce high flow volumes in a very short time. A major factor in this unique event may have been the actual location of the thunderstorm as it moved through the area. If one watershed receives substantially more precipitation it is likely to produce more discharge. The highest intensity event recorded during the study period was in the Mays flume during the summer of 2001 (>16cfs or 453 liters/second). This event completely submerged the 3-foot (0.914 meter) high flume and deposited more than 1.5 feet (0.686 meters) of sediment in the flume bottom. Jensen flume also recorded flow during this event but never exceeded 0.5664 liters/second (approximately 2.54 centimeters of stage).

Mays flume achieved higher flows (approximately 0.09cfs or 2.55 liters/second) more frequently during all spring runoff periods other than the winter/spring period of 1999. According to the weather data, December of 1998 and January of 1999 displayed unusually high daytime temperatures in conjunction with low nighttime temperatures and rain-on-snow events. This led to sporadic surface runoff during peak flows of greater than

2.0cfs (56.64 liters/second) in Jensen and sustained flows of greater than 0.20cfs (5.664 liters/second) in Mays watershed. During this early runoff event, Jensen flume registered numerous peak flows compared with Mays flume data, demonstrated a gradual increase and gradual decrease of data, more typical of winter/spring runoff.

Flow duration

Similar to the intensity of flow, duration of surface flow in Mays watershed appeared to be longer than in Jensen watershed. Data from all of the events that produced flow in both watersheds showed Mays watershed to flow longer than Jensen watershed. As discussed in the geomorphometry section, this is very likely a result of the complexity of the drainage density in Mays watershed compared with Jensen's drainage density. Visual observation of the Mays watershed during spring runoff showed the majority of the main channel flow to be a result of seepage from the channel walls rather than flow from the first and second order systems. Jensen watershed had a similar phenomenon but with the flow originating in a percolating manner from the bottom of the main channel. The primary watershed factor that appears to drive this process is basin geomorphology. In areas where the basin is constricted to a narrow drainage bottom with a presence of bedrock, the channel would present surface flow during regular events. When the basin widens out or consists of an alluvial fan resulting from secondary channel drainage, the channel flow appears to tend towards subsurface flow in less extreme runoff events.

Flow frequency

Mays flume and datalogger recorded flow for all of the years of data collection, except 2003. Jensen flume and datalogger recorded flow for only a portion of the years of data collection. The data show that Mays not only flowed more often at the flume location but also tend to demonstrate higher volumes and duration of flow than the data indicates at the Jensen flume location.

Flume location was probably the primary reason for the large differences in flow data between the two watersheds. The Jensen flume is located within an alluvial fan at the lower end of the watershed. Mays flume is located at the uppermost section of an alluvial fan at the approximate midpoint of the watershed. The alluvial fan can act as a sponge, absorbing the channel flow.

Flow during this season appeared to originate as seepage from the channel bottom rather than overland flow from the banks of the channel. In order for the Jensen flume to receive flow, it either needed to be an event extreme enough to exceed the summer rate of infiltration or happen during a time of year when the soil was at field capacity or frozen. This is also the case for Mays, but because the Mays flume location was at a site where the basin is nearly constricted, there was more opportunity for surface flow.

Subsurface flow

Measurement of subsurface flow or presence of groundwater gave some insight as to what was going on when surface flow was not present at both flumes. The well installation of 1996, mainly acted as a tool to give some insight as to subsurface flow differences between the two study areas and provide some guidance as to what to do next time. Due to the well depth, location, and ability to read the wells, they did not prove useful for building a solid data set. In general, all but one of the wells (ADH #5 located in Jensen) was shallow and typically demonstrated no presence of water (Appendix P).

The well that did consistently provide data gave a good picture of the seasonal fluctuations in subsurface water. Well #5 in the Jensen watershed consistently showed a presence of groundwater. Presence of water in this well seemed to approximate the data of flow in the Mays flume. From this observation, we determined that it would be useful to install new, deeper wells in each watershed. In 2003, the new wells were installed down to the groundwater level and relocated below the flume location in Mays watershed. Since their installation, the new wells have produced data from both watersheds on a consistent basis.

Data from the preliminary analyses of these wells displayed in Figure 28, similar seasonal groundwater levels in the two watersheds. This figure also showed the timing of groundwater recharge in the two watersheds in relation to snowmelt in early spring. This data also showed Jensen watershed to be slightly behind Mays watershed in the timing of the recharge as well as the release of the groundwater from the system.

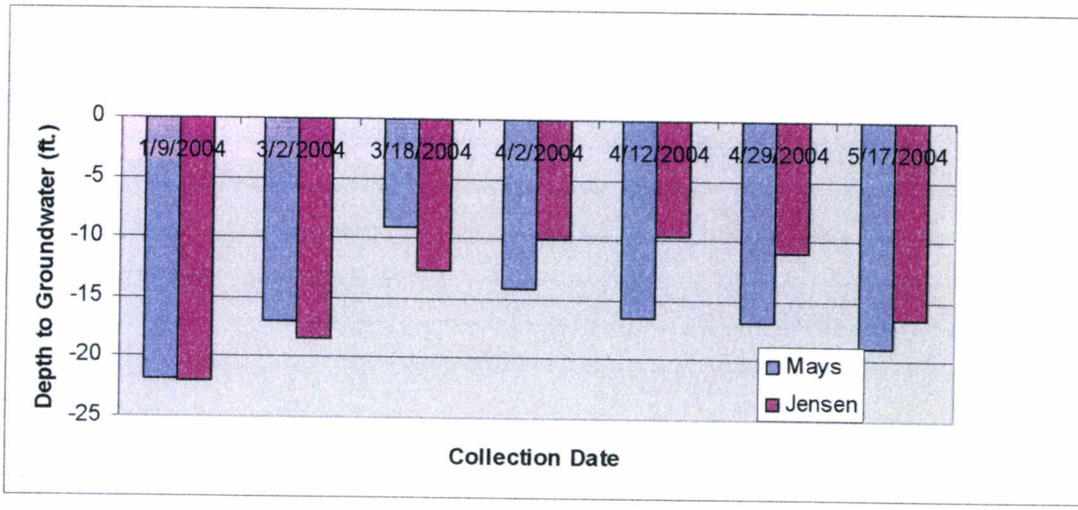


Figure 28. Depth to groundwater in wells installed in December of 2003.

As mentioned before, this was only preliminary data, but it did support the surface-runoff data by displaying a similar pattern, while simultaneously providing a potentially complete data set.

MAIN CHANNEL EROSION PROCESSES

The original intent of the cross-sectional plots was to provide: (1) a morphological description of the channel, (2)an indirect approach to determining the impact of flow events on the channel morphology, and (3) a means of estimating flow at 30-meter intervals along the channel, using the estimated active channel area. The morphological description was in place and provided an opportunity for comparison of channel structure changes on a biannual basis. However, using the cross-sections to estimate discharge measurements required actual channel discharge measurements could be used in conjunction with estimated active channel area to extrapolate flow at the point of the cross-section plot. As discussed in the hydrology section, the flow was sporadic at best. Even when flow occurred in the flume, it may only be apparent as surface flow in a portion of the main channel of either watershed.

In general, the data showed the two watersheds to behave similarly over time relative to different weather events. When compared on a plot-by-plot basis using the sums of differences, the two watersheds were statistically different. In contrast, the two watersheds were not statistically different when comparing average changes over time. The reason for this difference in statistical products may have been in the sheer magnitude of the values that accumulated when summing the differences.

The cross-section plots provided useful information to assist in the long-term calibration process relative to channel dynamics and morphology. The graphical representation in Appendix O shows that during the larger flow events, such as summer 2001 most of the channel change is in the form of scour from the bottom of the channel. There was evidence of channel widening due primarily to sloughing of channel sides, a natural process in any channel that had experienced excessive downcutting.

Sedimentation data revealed that both Mays and Jensen watersheds displace a reasonable amount of soil during summer storm events. During a major summer precipitation event in 1996, both watersheds experienced a substantial amount of overland flow. This flow was evidenced by the high volume, short duration discharge obtained in the Mays watershed flume. Other indicators of this event included the elevation differences obtained with the sedimentation rods and the obvious soil displacement that occurred in the channel bottoms. Of the 11 periods of data collection, data showed only one period (fall, 1999) to represent a significant difference between the two watersheds. The remaining 10 periods showed some differences in soil movement but not at a significant level. Due to the periods actually encompassing different lengths of time, it would be inappropriate to draw strong conclusions on the differences between the collection periods.

HILLSLOPE EROSION PROCESSES

The intent of the sediment stake data was to provide a quantifiable estimate of the differences in hillslope erosion potential for the two watersheds. The data showed Jensen watershed to be more erodible within the hillslope sub-drainages (gullies). In most years, the sediment stake data demonstrated only minimal soil movement. Where the stakes proved especially useful was in capturing more extreme events such as the summer of 1996. These are likely the events responsible for most of the channel formation in this type of system. The annual runoff events move minimal material and tend to just transfer soil from one point on the hillslope to another, rather than moving it all the way down into the main channel. The latter is much more significant because of potential effects on surface soil and site characteristic, as well as water quality and channel characteristics.

CONCLUSION

This study looked at the 10-year calibration phase of a longer-term project studying the impact on streamflow. The intent of this study during the calibration period was to determine similarities and differences of a variety of parameters of Mays and Jensen watersheds. With ample data, it is assumed that the behavior of different processes on one watershed could then be predicted through the behavior of those same processes on the adjacent watershed. Natural variation under wildland conditions is almost always high; in the case of semi-arid watersheds these natural extremes are exacerbated. Depending upon the level of confidence placed upon the data, ten years of data from a semi-arid environment may be adequate statistically. Nevertheless, from a pragmatic, preponderance of evidence point of view, a ten-year calibration period on such a watershed is unique and extremely data-rich. I acknowledge the statistical limitations associated with these circumstances while at the same time recognize that a study such as this is a dramatic boon toward the scientific management of desert and semi-arid watersheds in Oregon.

HYDROLOGY

As mentioned earlier in the results and discussion sections, the hydrologic portion of this project proved to be a very challenging element. The 10-year calibration period did not provide sufficient hydrologic events to develop a flow prediction equation for post-treatment comparative use. The well data showed good promise as a predictive tool, in particular when used in conjunction with spring output data. In combination, these three parameters captured the trends in the hydrologic processes.

Measurement of flow over different reaches of the channel appeared to be a needed component for this type of study. Since flow occurred from several origins and within different reaches of the study area channels, there should probably have been some means of accounting for this water movement. Subsurface flow may have been the key component for what occurred in the study areas.

Well transects placed adjacent to the flume may provide the missing piece of the puzzle. The wells should be buried to a depth of at least the first sign of groundwater, probably through at least one impermeable layer. The interval between the wells should be such that the inherent variation in the subsurface geology of the study area is captured. The wells should be designed for year-round monitoring on at least a daily basis and protected from livestock impact, as well as be easy to find during snow events.

Surface flow should be accounted for at a location other than the bottom-end of each study area. This poses a more difficult question. Instrumentation of the upper channel needs to be cost effective, yet still produce credible data. One method may be to fabricate a rudimentary weir or flume at equal distances upstream from both in-place flumes. The measuring device would consist of a staff gauge that would yield relatively accurate measurements. Discharge measurements could than be correlated with appropriate area of input and compared between the two watersheds. If the stream channels yielded surface flow at different points along the stream, they could still provide useful comparable relationships. The two spring locations also provided a good opportunity for quantifying the hydrologic processes of the two watersheds. Both springs tend to flow for greater lengths of time than the surface flow events. Monitoring of spring output may correlate nicely with the well data and capture a large portion of the lost hydrologic information that is not picked up by the surface flow data.

EROSIONAL PROCESSES

Quantitative analysis of the erosional processes of each watershed was attempted through hillslope erosion stakes and main channel cross-sections. Both of these forms of measurement proved useful for describing the erosional processes. The risk of data corruption due to frost heaving and/or other processes which might alter stake height was minimized by driving the stakes as deeply into the soil mantel as was practical. The stakes were not leveled and the probability exists that they could have moved during the 10-year calibration period. This was guarded against in the field and during the data compilation/analysis phase. The field check of the stakes occurred while measuring the cross-sections. Each cross-section measurement involved using a carpenter's square to hold the vertical ruler in place in order to obtain depth measurements. During this time, it was possible to determine whether one side or the other had been moved by checking the carpenter's square for level. If the carpenter's square was out of level, then it was assumed that one of the two stakes had in fact moved. When this occurred, it appeared to be mainly the result of livestock activity during muddy conditions. The stake that had been altered could usually be identified by the excess activity at the base of the stake. During data analysis, values that appeared out of the ordinary or without explanation were treated as outliers and removed from the sample. While theoretically frost heaving may have occurred equally to both sides of the cross-section stakes or at a level that would not draw attention during analysis, that probability seems remote.

Since spring runoff appears to be influenced by surface soil temperature and moisture content, it seems logical to attempt to quantify these two parameters. Low soil temperatures and high soil moisture content combined can produce an impermeable frozen soil layer such as the one that appeared to drive the winter of 1999 runoff event. There is no quantifiable data to support this hypothesis as it stands, but this could be remedied if these parameters could be captured in future events. Soil temperature and soil moisture will be measured parameters in future studies.

GEOMORPHOMETRY

Identifying different geomorphological parameters and processes proved to be a worthwhile endeavor. Measurement of geomorphological parameters has long been considered a valuable asset to understanding watershed processes. For the sake of this study, geomorphometry fit better as a qualitative analysis tool rather than a quantitative statistical tool. The use of geographical information systems (GIS) has dramatically simplified the application of geomorphometry; however, they both require extensive effort and knowledge to apply them appropriately.

One element adding to the complexity of the analysis is choosing which type of software to use. In a long-term study such as this, it is especially important that the data and information be kept up-to-date or in a format that will allow for future analysis. In 1994 the GIS phase of this project began with the use of IDRISI© software. At the time, it was easily accessible and affordable. Although some of the earlier analysis such as slope and aspect comparisons, exists in this document, the bulk of the remaining analysis was accomplished using MicroDEM©. ArcMap© is another GIS software tool that had some utility in this project. ArcMap© is the standard for agency use as well as being the primary GIS software for academic research.

Each of these software packages has their pros and cons. MicroDEM© provides multiple geomorphic analysis tools and is freeware, but does not have the presentation quality of IDRISI or ArcMap©. ArcMap© has an extensive analysis package but requires extensive training to be efficient in its use and is also substantially more expensive than either of the other two packages. Future GIS work in this study will entail the use of ArcMap due to availability of this software through the OSU Department of Rangeland Resources and Prineville District of the Bureau of Land Management.

LESSONS LEARNED

Often the lessons learned in the setting up of a study are as important as the study itself. One of the key points that came into play in this study was "keep it simple." The more complicated the instruments or methods become, the more opportunity there is for mistakes and breakdowns. In some cases, the complicated equipment even makes it more difficult to detect problems until it is too late.

An example of "keeping it simple" is the use of sandbags as barriers against seepage at the front of the flume-approach. Although the sandbags are probably the most basic method for stabilizing this area (as compared to cold-patch asphalt, visquien plastic, metal shields, and geo-textile materials), they proved to be the most functional. Another example would be the sedimentation rods used to determine erodible properties of soil scour and deposition. The rods are very basic but should have withstood the test of time and are proving to provide some very useful and easily interpreted data.

On the other hand, the programming of the data loggers proved to be better suited to complex programming rather than simple programming in order to obtain workable, meaningful data. Initially the data logger was set to record data every 10 minutes whether there was an event or not. This provided an over abundance of meaningless data. Reprogramming the data loggers with a program of greater complexity provided less data to analyze with more data of greater utility.

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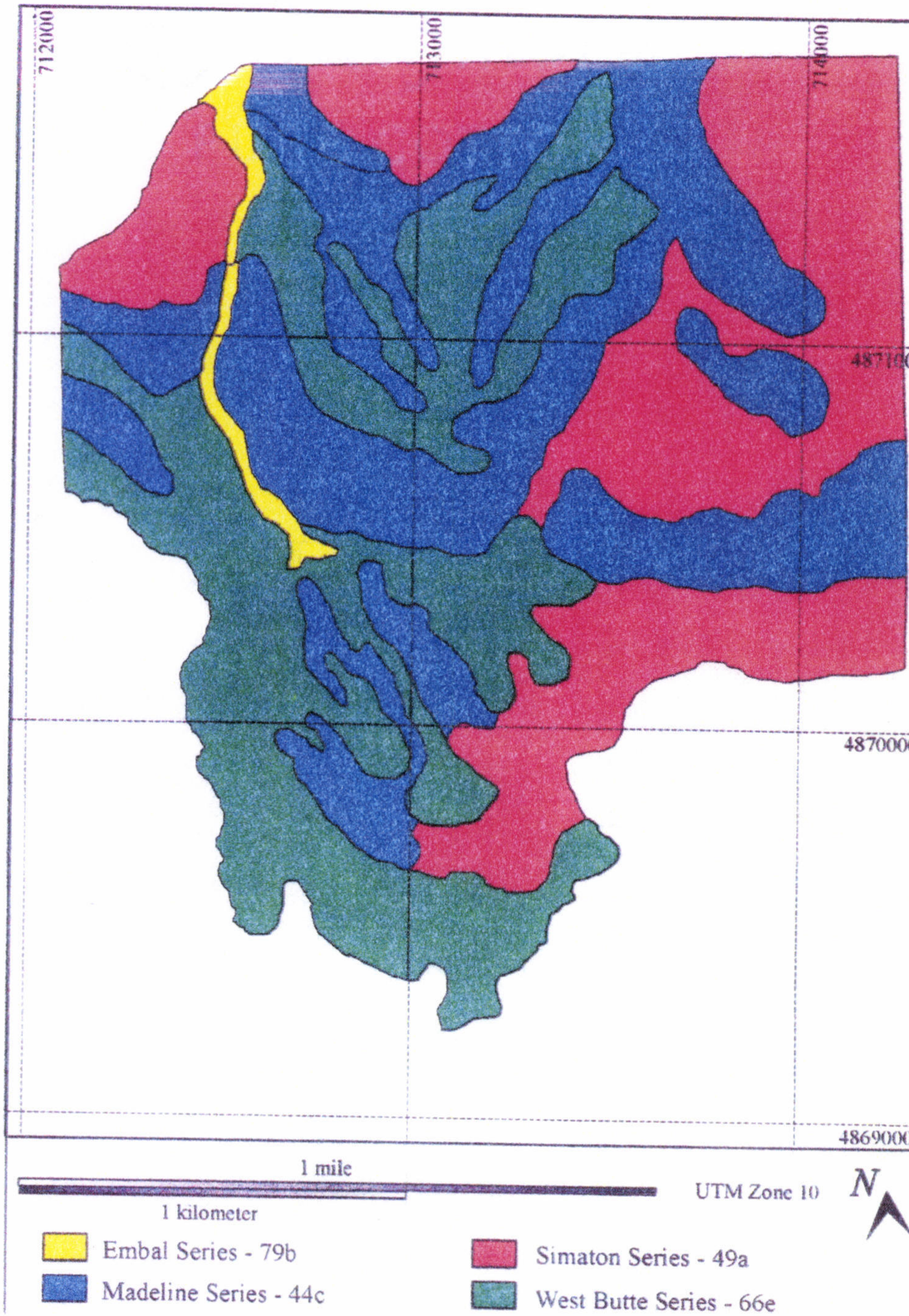
APPENDICES



Appendix A. Soil series distribution.

Appendix B. Partial plant species list.

Perennial Grasses

Agropyron spicatum	bearded blubunch wheatgrass
Elymus glaucus var *glaucus*	blue wildrye
Festuca idahoensis	Idaho fescue
Koeleria cristata	prairie junegrass
Oryzopsis hymenoides	indian ricegrass
Poa ampla	big bluegrass
Poa sandbergii	sandberg bluegrass
Olypogon monspeliensis	rabbitfoot grass
Sitanion hystrix	bottlebrush squirreltail
Stipa comata	needle-and-thread
Stipa occidentalis	western needlegrass (columbiana)

Sedge-Rush

Carex geyeri	elk sedge

Annual Grasses

Bromus tectorum	cheatgrass brome

Perennial Forbs

Achillea millefolium	common yarrow
Antennaria stenophylla	pussy toes
Arenaria frankinii	Sandwort
Balzamorhiza sagittata	arrowleaf balsamroot
Calacohortus macrocarpus	sagebrush mariposa
Chaenactis douglasii	Douglas c./False yarrow
Erigeron linearis	lineleaf fleabane (yellow)
Gilia aggregata var *aggregata*	skyrocket scarlet gilia
Geum trifolium	prairie star
Lithospermum ruderale	Stoneseed
Lupinus	
Penstemon eriantherus	fuzzy tongue
Phacelia hastata	silverleaf phacelia
Salvia dorrii	greyball sage
Senecio integerrimus	western groundsel

Appendix B. Partial plant species list continued.

Biennial Forbs

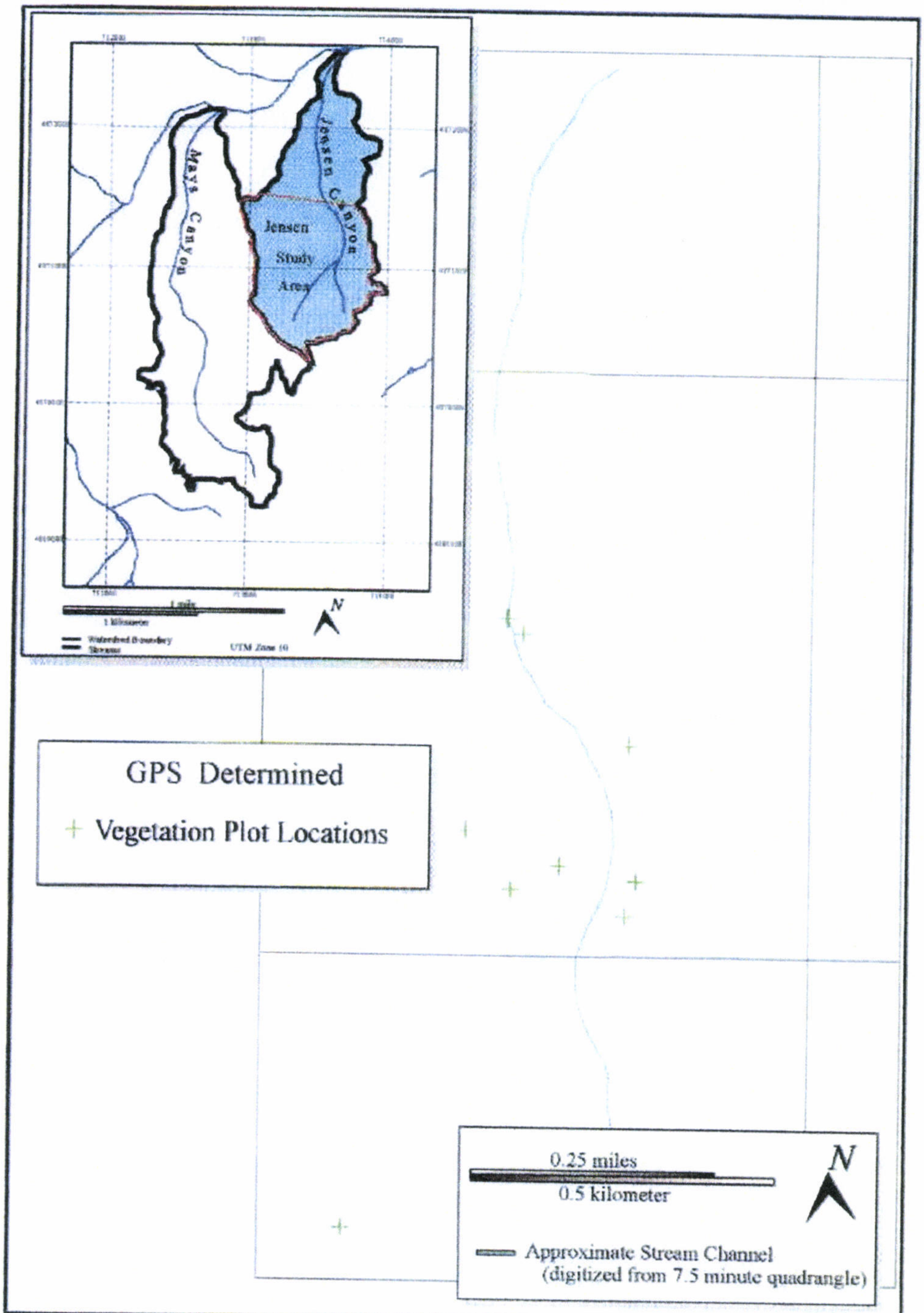
Tragopogan dubius	yellow salsify

Annual Forbs

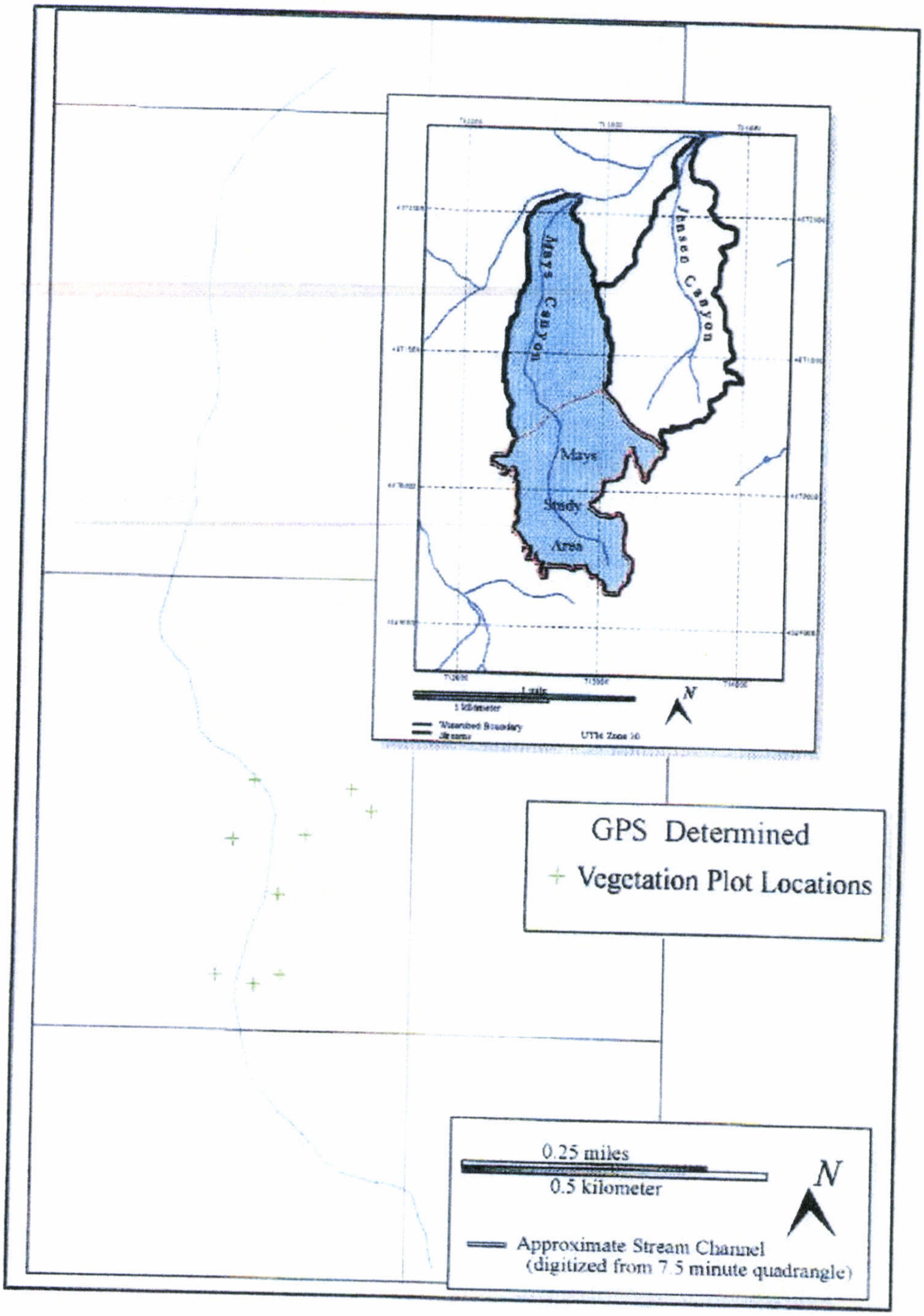
Collinsia grandoflora	pagoda plant
Collomia grandiflora	bigflower gilia
Cordylanthus ramosus	bushy birdbeak
Erysimum occidentale	pale wallflower
Lygodesmia juncea	rush skeletonweed
Mimulus breweri	crimson monkeyflower

Shrubs and Trees

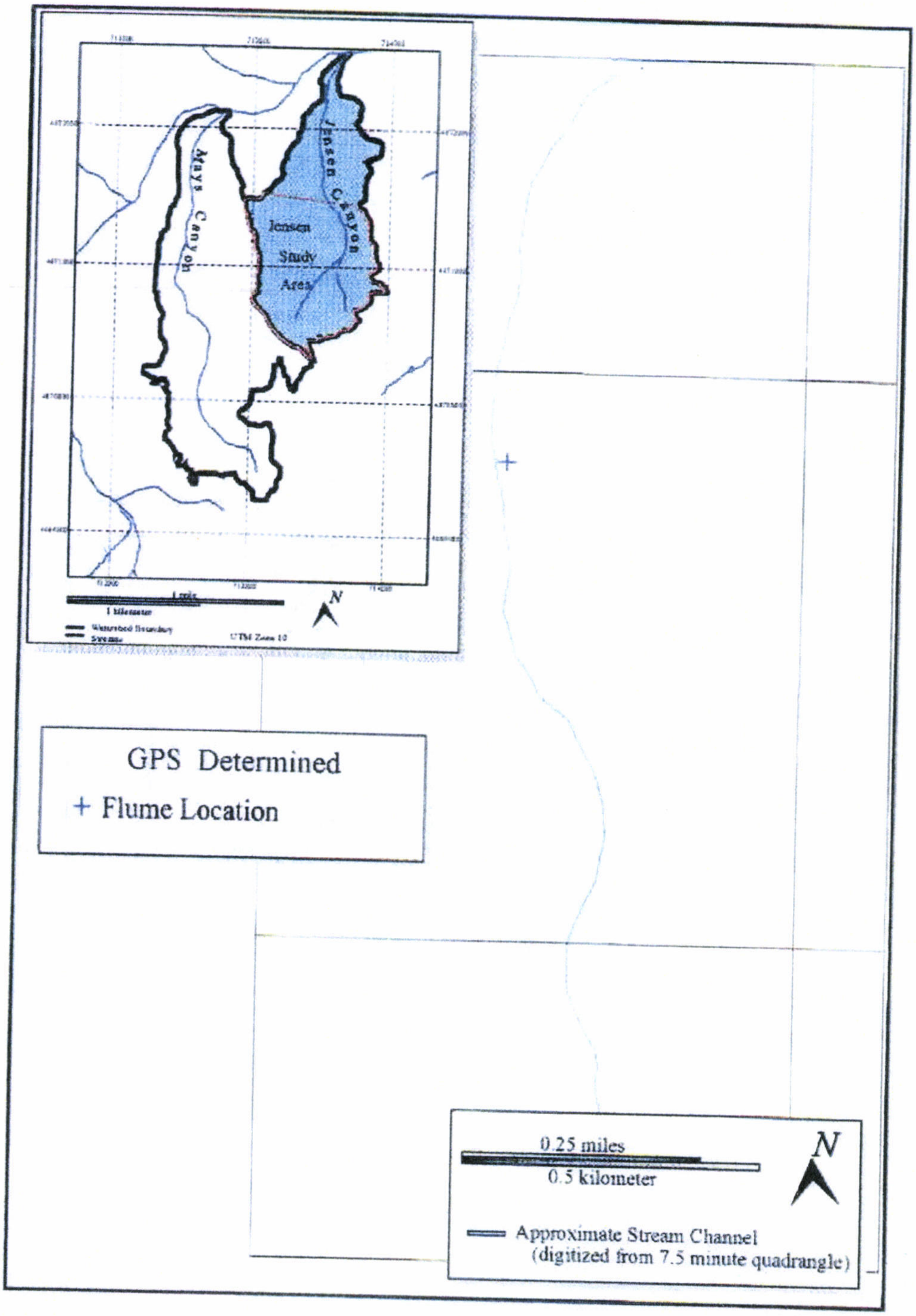
Amelanchier alnifolia	pacific serviceberry
Artemisia ludoviciana	prairie sage
Artemisia tridentata	
ssp. tridentata	basin big sagebrush
ssp. wyomingensis	Wyoming big sagebrush
ssp. vaseyana	mountain big sagebrush
Atriplex spinosa	
Cercocarpus ledifolius	curlleaf mountain mahogany
Chrysothamnus nauseosus	gray rabbitbrush
Chrysothamnus viscidiflorus	green rabbit brush
Holodiscus dumosus	little oceanspray
Juniperus occidentalis	western juniper
Pinus ponderosa	ponderosa pine
Purshia tridentata	bitterbrush
Ribes cereum	wax current
Sambucus racemosa	elderberry
Symphorycarpos albus	snowberry
Tetradymia canescens	gray spineless horsebrush



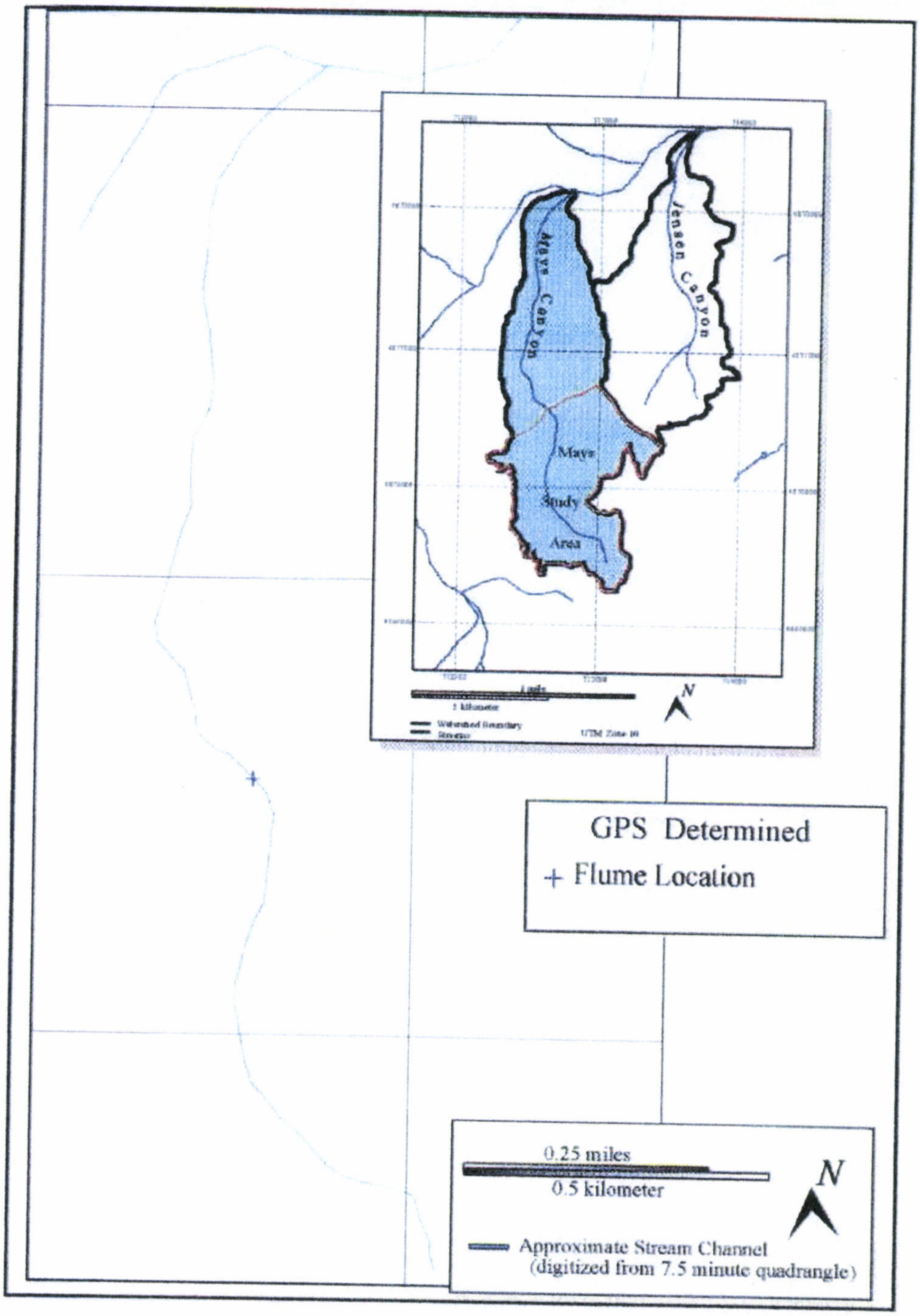
Appendix C1. Map of Jensen vegetation transect locations.



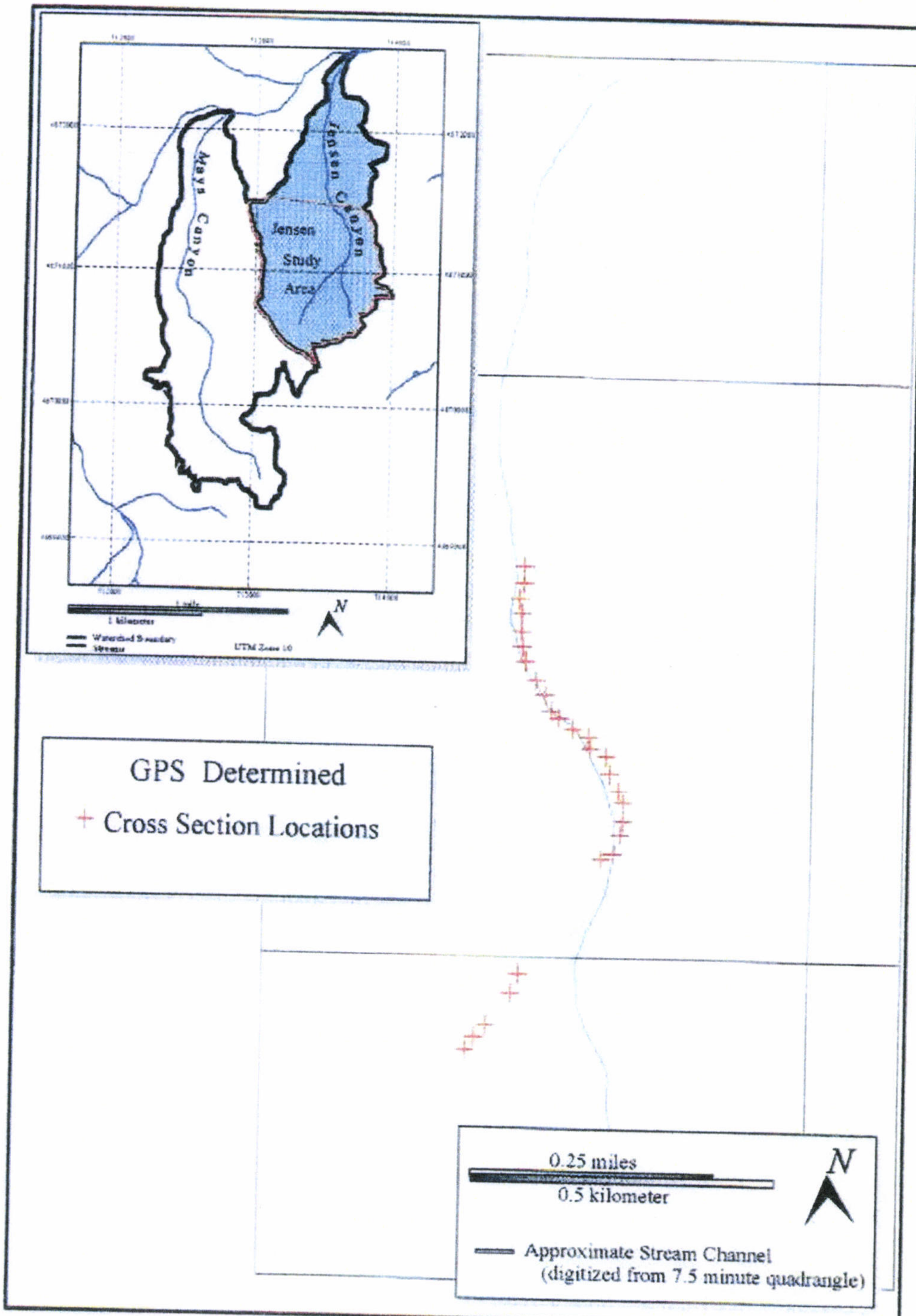
Appendix C2. Map of Mays vegetation transect locations.



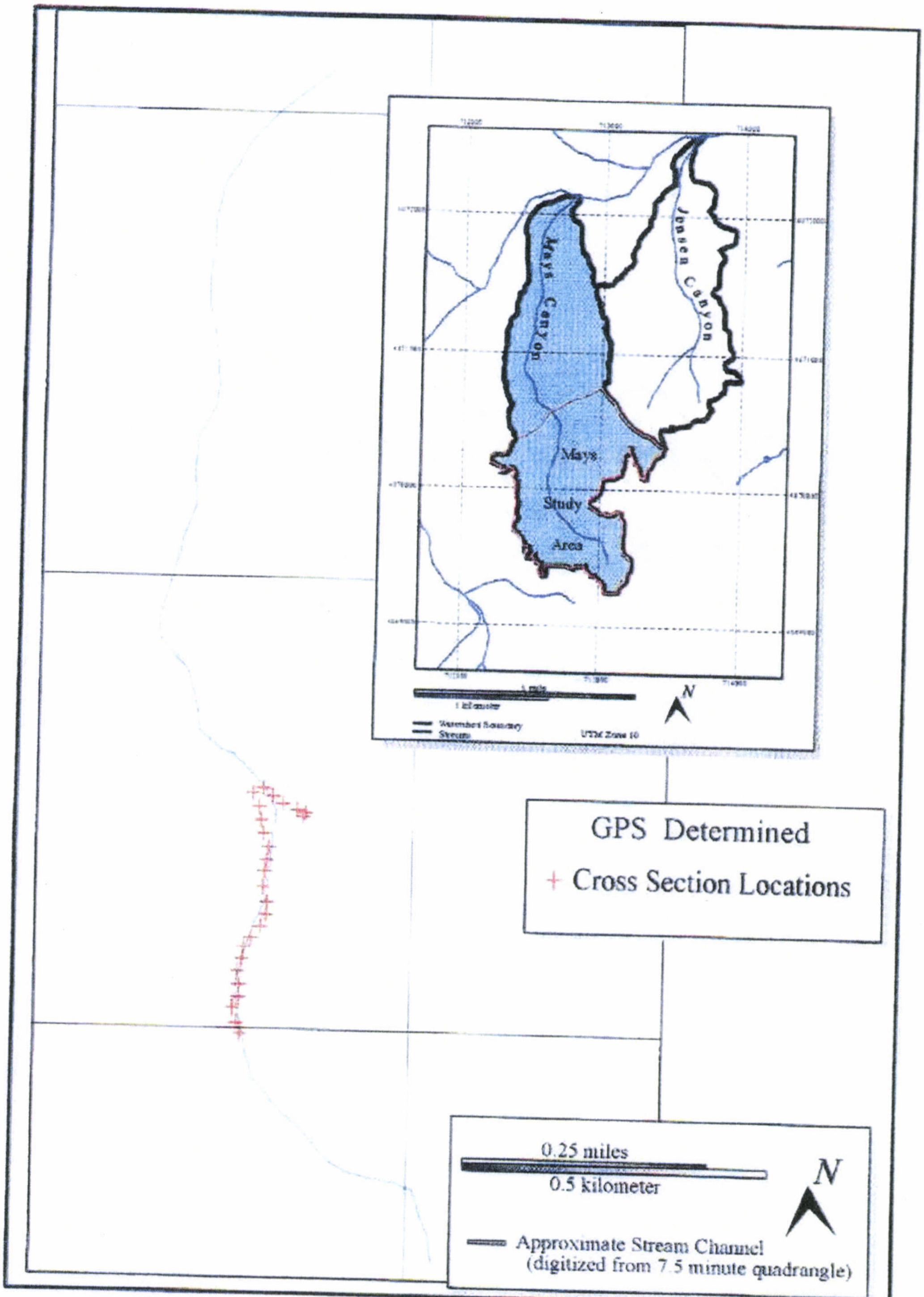
Appendix C3. Map of Jensen flume location.



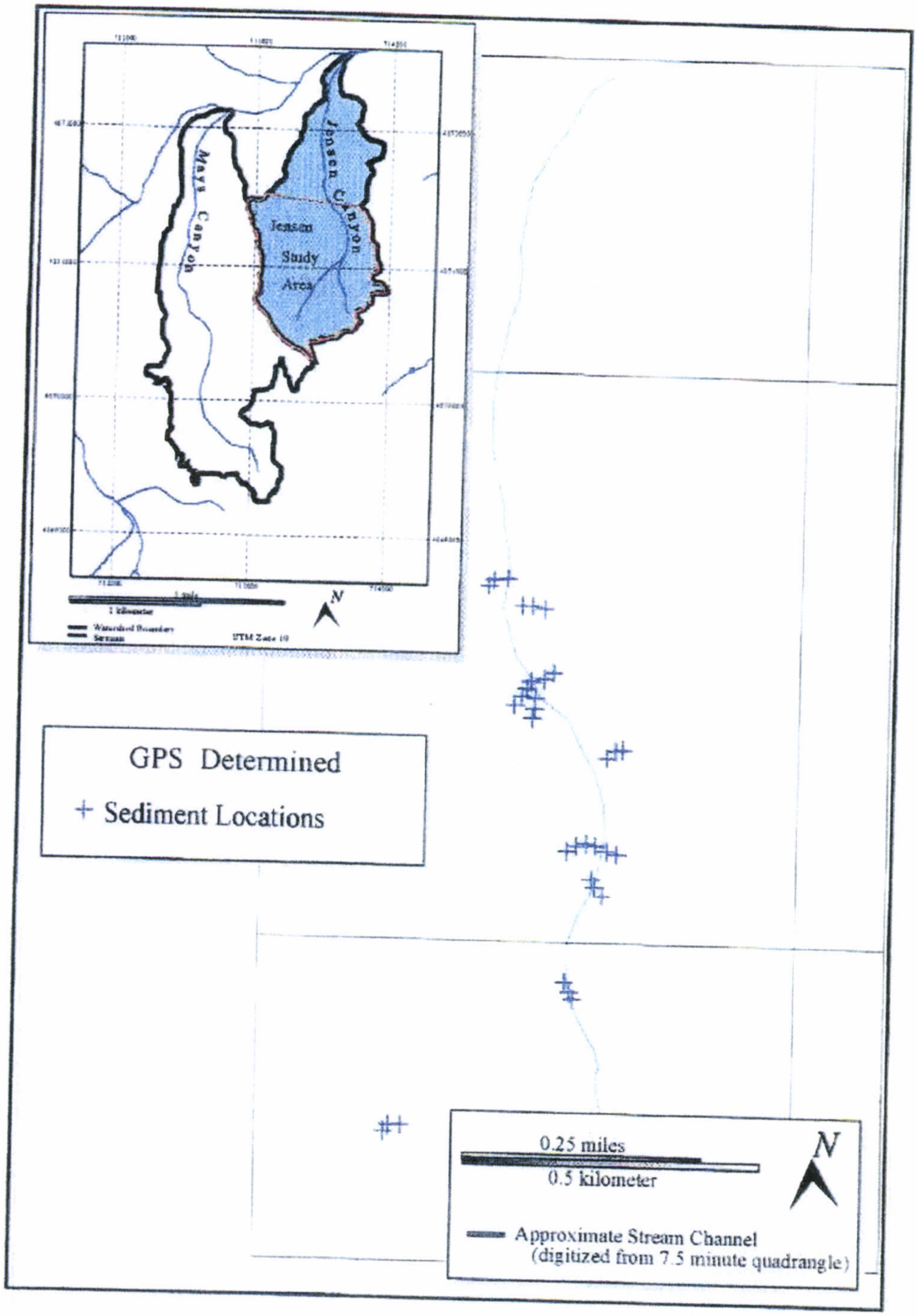
Appendix C4. Map of Mays flume location.



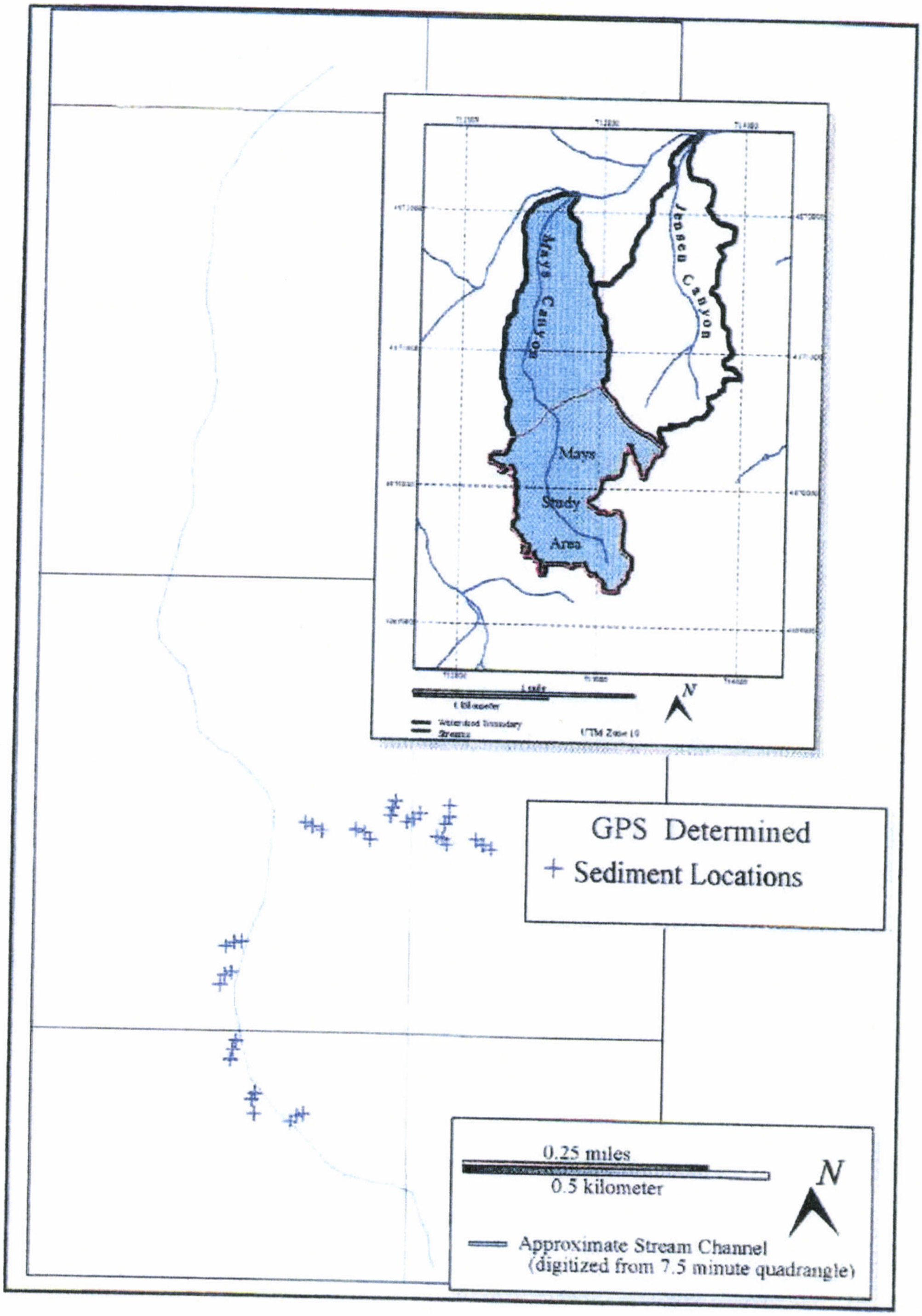
Appendix C5. Map of Jensen cross-section plot sections.



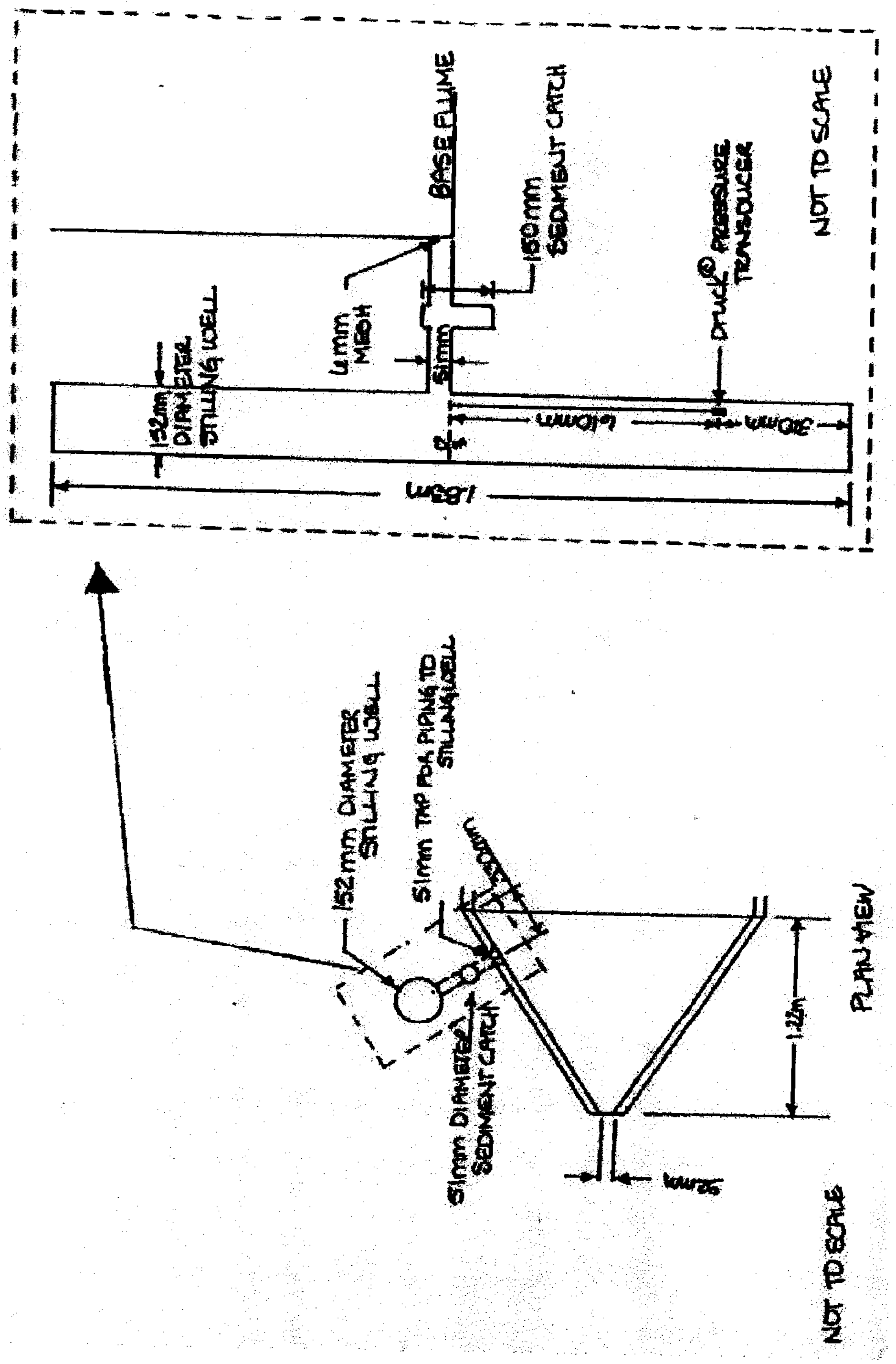
Appendix C6. Map of Mays cross-section plot locations.



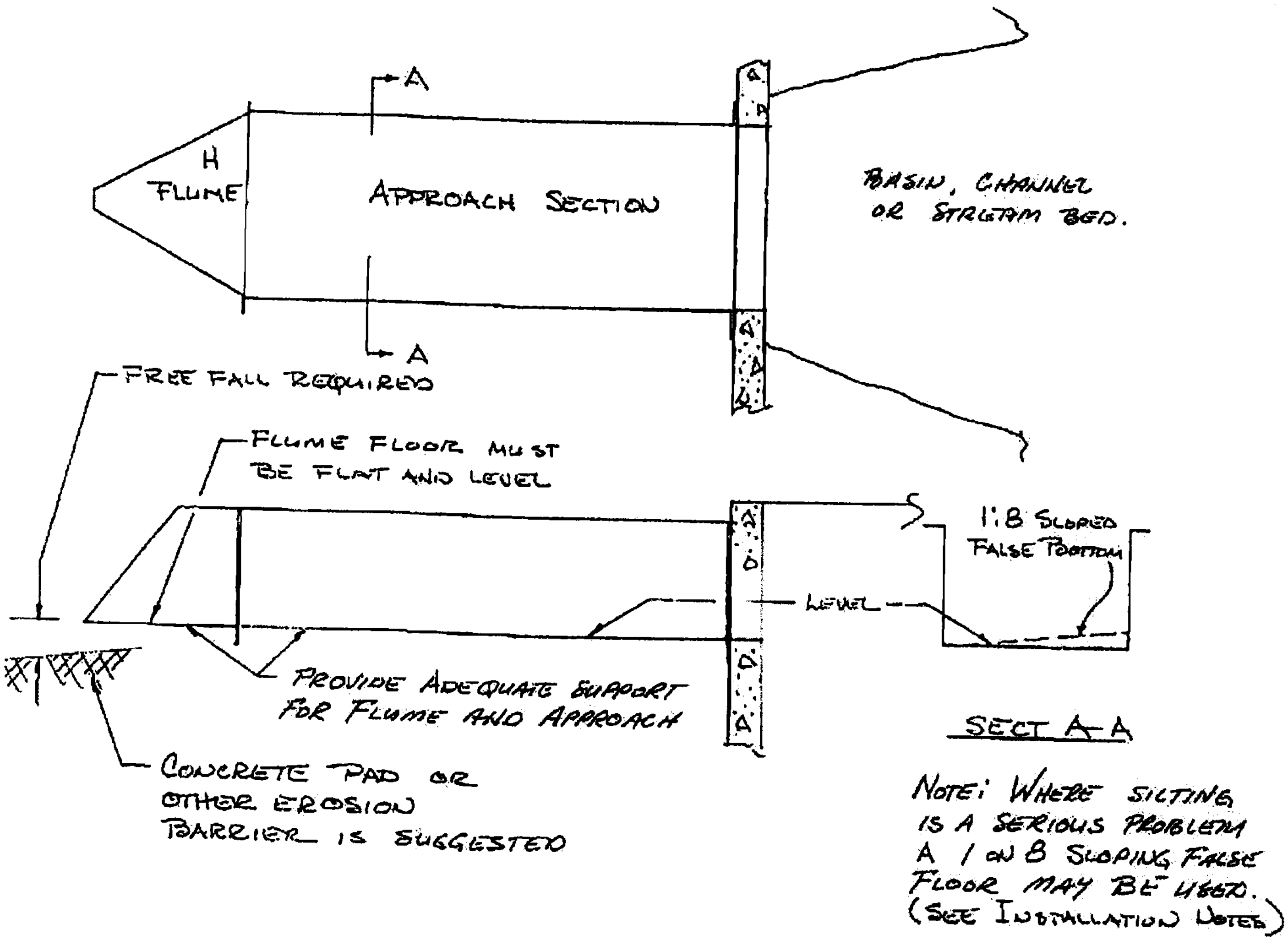
Appendix C7. Map of Jensen watershed hillslope erosion plot locations.



Appendix C8. Map of Mays watershed hillslope erosion plot locations.



Appendix D. Planned view of flume and stilling well with schematic of stilling well and pressure transducer locations.



Appendix E. Flume layout.

Appendix F. Datalogger program used to collect flow data on 10-minute intervals when minimum stage of 1.27cm is measured.

```
Program:
Flag Usage:
Input Channel Usage:
Excitation Channel Usage:
Control Port Usage:
Pulse Input Channel Usage:
Output Array Definitions:

*      1       Table 1 Programs
  01: 10       Sec. Execution Interval

01:  P10       Battery Voltage
  01: 1        Loc :

02:  P6        Full Bridge
  01: 1        Rep
  02: 3        25 mV slow Range
  03: 1        IN Chan
  04: 1        Excite all reps w/EXchan 1
  05: 2500     mV Excitation
  06: 2        Loc :
  07: 1.0545   Mult (1.0523 for Mays)
  08: -.82442  Offset

03:  P92       If time is
  01: 0        minutes (seconds--) into a
  02: 10       minute or second interval
  03: 10       Set high Flag 0 (output)

04:  P80       Set Active Storage Area
  01: 3        Input Storage Area
  02: 3        Array ID or location

05:  P73       Maximize
  01: 1        Rep
  02: 00       Value only
  03: 2        Loc

06:  P92       If time is
  01: 0        minutes (seconds--) into a
```

Appendix F. Data logger program continued.

```
  02: 10        minute or second interval
  03: 10        Set high Flag 0 (output)
07:  P89        If X<=>F
  01: 3         X Loc
  02: 3         >=
  03: .05       F
  04: 30        Then Do

08:  P80        Set Active Storage Area
  01: 1         Final Storage Area 1
  02: 103       Array ID or location

09:  P94        Else

10:  P80        Set Active Storage Area
  01: 3         Input Storage Area
  02: 10        Array ID or location

11:  P77        Real Time
  01: 1110      Year,Day,Hour-Minute

12:  P71        Average
  01: 1         Rep
  02: 2         Loc

13:  P73        Maximize
  01: 1         Rep
  02: 0         Value only
  03: 2         Loc

14:  P74        Minimize
  01: 1         Rep
  02: 0         Value only
  03: 2         Loc

15:  P92        If time is
  01: 0         minutes (seconds--) into a
  02: 1440      minute or second interval
  03: 10        Set high Flag 0 (output)
```

Appendix F. Datalogger program continued.

```
16:  P80          Set Active Storage Area
  01: 1           Final Storage Area 1
  02: 20          Array ID or location

17:  P77          Real Time
  01: 1220        Year,Day,Hour-Minute

18:  P74          Minimize
  01: 1           Rep
  02: 00          Value only
  03: 2           Loc

19:  P73          Maximize
  01: 1           Rep
  02: 00          Value only
  03: 2           Loc

20:  P71          Average
  01: 1           Rep
  02: 2           Loc

21:  P74          Minimize
  01: 1           Rep
  02: 00          Value only
  03: 1           Loc

22:  P            End Table 1
*      2          Table 2 Programs
  01: 0.0000      Sec. Execution Interval

01:  P            End Table 2
*      3          Table 3 Subroutines

01:  P            End Table 3
*      A          Mode 10 Memory Allocation
  01: 28          Input Locations
  02: 64          Intermediate Locations
  03: 0.0000      Final Storage Area 2

*      C          Mode 12 Security
  01: 0000        LOCK 1
  02: 0000        LOCK 2
  03: 0000        LOCK 3
```

Appendix G. Precipitation data in millimeters from raingauges located near Jensen and Mays flumes.

JENSEN - YEAR: 1995

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0	0	0	0	6.4	5.1	0	0	0	7.6	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	2.5	6.4	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	1.3	6.4	0	0	0	0	0	0
7	0	0	0	0	0	0	6.4	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	2.5	0	0	0	0
11	0	0	0	0	5.1	0	0	0	0	0	0	0
12	0	0	0	0	0	0	3.8	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	10	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	1.3	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	1.3	3.8	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	7.6	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0
29	0		0	10	0	0	0	0	0	0	0	0
30	0		0	0	0	0	0	0	0	0	0	0
31	0		0		0		0	0		0		0

Appendix G. Continued.

JENSEN - YEAR: 1998

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0	0	3.8	0	3.8	0	1.3	5.1	0	0	0	0
2	0	0	0	0	1.9	0	0	0	0	0	0	1.3
3	0	0	0	4.4	0	0	0	0	0	0	2.5	3.2
4	0	0	0	0	10	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	6.4	0	0	0	0	0	1.9	1.3
7	0	0	0	0	0	1.9	0	0	0	0	0	0
8	0	0	3.2	0	0	3.8	0	0	3.8	0	6.4	1.3
9	0	0	0	4.4	0	0	0	0	0	1.3	4.4	0
10	0	0	1.3	0	0	0	0	0	0	0	2.5	0
11	0	0	0	0	11	0	0	0	0	0	0	0
12	0	0	0	0	1.3	0	0	0	0	0	0	0
13	0	0	0	1.9	0	0	0	0	0	0	0	0
14	0	0	0	3.2	3.2	0	0	0	0	0	0	0
15	0	0	0	0	10	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	2.5	0
17	0	0	0	0	0	0	0	0	0	0	3.8	0
18	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	2.5	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	1.9	0
21	0	0	5.1	0	0	1.3	0	0	0	0	13	0
22	0	0	0	0	0	0	0	3.2	0	0	6.4	0
23	0	0	0	5.1	0.6	0	0	0	0	0	11	0
24	0	0	0	0	10	6.4	0	0	3.8	1.3	0	0
25	0	0	0	0	0	1.9	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	1.3	0
27	0	0	0	0	1.9	0	0	0	0	0	2.5	0
28	0	2.5	0	0	39	0	0	0	0	0	0	18
29	0		0	0	0	0	0	0	0	0	4.4	0
30	0		0	0	0	0	0	0	0	0	3.2	0
31	0		5.1		0		7.6	0		13		7.6

Appendix G. Continued.

JENSEN -YEAR: 1999

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0	0	0	0	10	0	0	3.8	0	0	0	0
2	0	0	0	0	1.3	0	0	0	0	0	0	5.1
3	0	0	0	0	3.8	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	6.4	0	0	2.5	0
5	0	0	0	2.5	0	0	0	1.3	0	1.3	0	0
6	0	0	0	0	1.3	0	0	0	0	0	0	0
7	0	7.6	0	0	0	0	0	0	0	0	0	2.5
8	0	0	0	5.1	0	0	0	0	0	0	0	0
9	0	0	0	1.3	0	0	0	0	0	0	0	3.8
10	0	6.4	0	1.3	2.5	0	0	1.3	0	0	0	1.3
11	0	0	0	2.5	0	0	0	0	0	0	0	0
12	2.5	0	0	0	0	0	0	0	0	0	0	1.3
13	2.5	0	2.5	0	1.3	0	0	1.3	0	0	0	1.3
14	5.1	6.4	0	0	0	0	0	0	0	0	0	0
15	10	0	0	0	0	0	0	0	0	0	0	0
16	10	0	0	0	2.5	0	0	0	0	0	0	0
17	24	10	0	0	0	0	0	0	0	0	2.5	5.1
18	25	10	0	0	0	0	0	0	0	0	0	0
19	29	0	0	0	0	0	0	0	0	0	0	0
20	30	0	0	0	0	0	0	0	0	0	0	0
21	34	2.5	0	0	0	0	0	0	0	0	0	0
22	34	0	0	0	0	0	0	7.6	0	0	0	0
23	43	2.5	0	0	0	0	0	0	0	0	2.5	0
24	51	0	0	0	0	0	2.5	0	0	0	1.3	0
25	51	1.3	0	0	0	0	0	0	0	11	3.8	0
26	51	0	1.3	0	0	0	0	0	0	5.1	1.3	0
27	51	5.1	1.3	0	0	0	1.3	0	0	0	0	0
28	51	2.5	0	0	0	0	0	5.1	0	0	0	0
29	51		2.5	0	0	0	0	0	0	0	0	0
30	51		0	0	0	0	0	0	0	0	0	0
31	51		3.8		0		0	0		0		0

Appendix G. Continued.

JENSEN - YEAR: 2000

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0	7.6	2.5	0	0	0	0	0	15	0	1.3	0
2	2.5	0	0	0	0	0	0	0	2.5	0	0	0
3	0	0	1.9	0	0	0	0	0	8.9	0	0	0
4	11	2.5	0	0	0	0	0	0	0	0	0	0
5	2.5	3.8	3.2	0	0	0	1.9	0	0	0	0	0
6	0	0	3.8	0	0	0	0	0	0	0	1.3	0
7	0	0	0	0	0	0	0	0	0	0	7.6	0
8	0	0	1.3	0	2.5	0	0	0	0	0	0	0
9	1.3	0	0	0	0	1.3	0	0	0	10	1.3	0
10	1.3	0	2.5	0	0	0	0	0	0	14	0	0
11	6.4	0	1.9	0	0	10	0	0	0	0	0	0
12	3.8	7.6	1.3	3.8	0	0	0	0	0	0	0	0
13	1.3	6.4	0	6.4	0	0	0	0	0	0	0	0
14	14	10	2.5	1.3	0	0	0	0	0	0	0	0
15	0	0	0	11	2.5	0	0	0	0	0	0	1.9
16	3.8	0	6.4	0	0	0	0	0	0	0	0	2.5
17	0	0	0	2.5	0	0	0	0	0	0	0	8.9
18	0	0	0	2.5	0	0	0	0	0	0	0	1.3
19	2.5	0	2.5	2.5	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	5.1	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	2.5
24	2.5	0	0	0	0	0	0	0	0	0	0	5.1
25	5.1	0	0	0	0	0	0	0	0	7.6	1.3	0
26	0	22	0	0	0	0	0	0	0	3.8	0	0
27	0	0	0	0	0	0	0	0	0	0	2.5	0
28	0	0	0	0	0	0	0	0	0	5.1	0	0
29	1.3	0	0	0	0	0	0	0	0	0	0	0
30	0		0	0	3.8	0	0	0	0	0	1.3	0
31	2.5		0		0	0	0	0		0		0

Appendix G. Continued.

JENSEN - YEAR: 2001

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0	0	0	0	0	0	0	0	0	0	0	3.8
2	0	0	0	0	1.3	0	0	0	0	0	0	2.5
3	0	1.3	2.5	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	14	0	0	0	29
5	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	2.5	0	0	0	0	0	0	0	0	2.5
7	0	0	0	0	0	0	0	0	0	0	0	8.9
8	0	0	0	0	0	0	0	0	0	0	0	0
9	0	5.1	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	1.3	0	0	7.6	0	0
11	1.3	1.3	0	0	0	2.5	0	0	0	0	0	0
12	0	1.3	0	6.4	0	0	0	0	3.8	0	0	0
13	1.3	0	0	0	0	0	0	0	0	0	10	0
14	0	0	8.9	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	5.1	0	5.1	0
17	0	0	0	8.9	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0
19	3.8	0	0	0	0	6.4	0	0	0	0	1.3	0
20	0	6.4	0	0	7.6	0	13	0	0	0	18	2.5
21	3.8	0	0	0	0	0	0	2.5	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	7.6	0	0	0	0	0	0	0	0	2.5
24	1.3	0	0	0	0	0	0	0	0	0	0	0
25	0	1.3	0	0	0	0	0	0	5.1	0	8.9	0
26	0	0	11	0	0	0	0	0	0	0	3.8	0
27	0	0	0	3.8	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	3.8	0
29	0		0	5.1	0	0	8.9	0	0	15	2.5	2.5
30	0		0	0	0	0	0	0	0	0	3.8	3.2
31	0		0		0		0	0		0		2.5

Appendix G. Continued.

JENSEN - YEAR: 2002

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	14	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	5.1	0	5.1	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0
7	1.3	1.3	0	0	0	0	0	0	0	0	0	0
8	0	0	0	5.1	0	0	0	0	0	0	0	0
9	0	0	0	0	0	3.2	0	0	0	0	0	0
10	0	0	0	5.1	1.3	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	17	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	3.8	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	3.8	0	0	0	0	0	0
18	2.5	4.4	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	5.1	0	0	0	0	0	0	0
20	5.1	0	0	0	0	0	0	0	0	0	0	0
21	1.3	0	0	0	0	0	0	0	0	0	0	0
22	2.5	0	0	0	0	2.5	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	15	0	0	0	0	0	0
27	0	0	0	0	0	5.1	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0
29	0		0	0	0	0	0	0	0	0	0	0
30	0		0	0	0	0	0	0	0	0	0	0
31	3.8		0		0		0	0		0		0

Appendix G. Continued.

MAYS - YEAR: 1995

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0	0	0	0	7.6	8.9	0	0	0	6.4	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	2.5	6.4	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	1.3	7.6	0	0	0	0	0	0
7	0	0	0	0	0	0	7.6	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	2.5	0	0	0	0
11	0	0	0	0	5.1	0	0	0	0	0	0	0
12	0	0	0	0	0	0	3.8	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	10	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	1.3	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	1.3	3.8	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	2.5	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0
29	0		0	10	0	0	0	0	0	0	0	0
30	0		0	0	0	0	0	0	0	0	0	0
31	0		0		0		0	0		0		0

Appendix G. Continued.

MAYS - YEAR: 1998

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0	0	5.1	0	3.2	0	1.3	5.1	0	0	0	0
2	0	0	0	0	1.3	0	0	0	0	0	0	1.9
3	0	0	0	5.1	0	0	0	0	0	0	3.2	3.8
4	0	0	0	0	13	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	5.1	0	0	0	0	0	2.5	1.9
7	0	0	0	0	0	2.5	0	0	0	0	0	0
8	0	0	3.8	0	0	2.5	0	0	3.8	0	10	1.3
9	0	0	0	4.4	0	0	0	0	0	1.9	1.3	0
10	0	0	1.3	0	0	0	0	0	0	0	4.4	0
11	0	0	0	0	13	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	1.3	0	0	0	0	0	0	0	0
14	0	0	0	4.4	3.8	0	0	0	0	0	0	0
15	0	0	0	0	13	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	4.4	0
17	0	0	0	0	0	0	0	0	0	0	3.2	0
18	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	2.5	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	1.9	0
21	0	0	7.6	0	0	1.3	0	0	0	0	15	0
22	0	0	0	0	0	0	0	3.8	0	0	7	0
23	0	0	0	5.1	1.3	0	0	0	0	0	12	0
24	0	0	0	0	11	7.6	0	0	5.1	1.3	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	1.3	0
27	0	0	0	0	2.5	0	0	0	0	0	2.5	0
28	0	5.1	0	0	41	0	0	0	0	0	0	17
29	0		0	0	0	0	0	0	0	0	4.4	0
30	0		0	0	0	0	0	0	0	0	3.2	0
31	0		6.4		0		8.9	0		13		0

Appendix G. Continued.

MAYS - YEAR: 1999

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	10	0	0	0	0	0	0	2.5
3	0	0	0	0	3.8	0	0	0	0	0	0	1.3
4	0	0	0	0	0	0	0	2.5	0	0	1.3	0
5	0	2.5	0	2.5	0	0	0	2.5	0	1.3	0	0
6	0	13	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	1.3
8	0	0	0	2.5	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	2.5
10	0	3.8	0	3.8	0	0	0	1.3	0	0	0	1.3
11	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	1.3
14	0	0	0	0	0	0	0	0	0	0	0	1.3
15	2.5	0	0	0	0	0	0	0	0	0	0	0
16	0	13	0	0	0	0	0	0	0	0	0	0
17	10	10	0	0	1.3	0	0	0	0	0	2.5	3.8
18	5.1	0	0	0	0	0	0	0	0	0	0	0
19	3.8	0	0	0	0	0	0	0	0	0	0	0
20	6.4	6.4	0	0	0	0	0	0	0	0	0	0
21	8.9	3.8	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0
23	7.6	0	0	0	0	0	0	5.1	0	0	1.3	0
24	7.6	0	0	0	0	0	0	0	0	0	2.5	0
25	0	0	0	0	0	0	0	0	0	8.9	2.5	0
26	0	7.6	1.3	0	0	0	0	0	0	5.1	1.3	0
27	0	3.8	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0
29	0		1.3	0	0	0	0	0	0	0	0	0
30	0		0	0	0	0	0	6.4	0	0	0	0
31	0		3.8		0		0	0		0		0

Appendix G. Continued.

MAYS - YEAR: 2000

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0	6.4	1.3	0	0	0	0	0	13	0	1.3	0
2	1.3	0	0	0	0	0	0	0	2.5	0	0	0
3	3.8	0	1.3	0	0	0	0	0	10	0	0	0
4	5.1	1.3	0	0	0	0	0	0	0	0	0	0
5	3.8	2.5	2.5	0	0	0	1.9	0	0	0	0	0
6	0	1.3	3.8	0	0	0	0	0	0	0	1.3	0
7	1.3	0	0.6	0	1.3	0	0	0	0	0	7	0
8	0	0	0	0	2.5	0	0	0	0	0	0	0
9	1.3	0	0	0	0	0	0	0	0	7.6	1.3	0
10	0	0	2.5	0	0	1.3	0	0	0	13	0	0
11	1.3	0	0	0	0	0	0	0	0	0	0	0
12	0	6.4	1.3	3.8	0	8.9	0	0	0	0	0	0
13	0	14	0	4.4	0	0	0	0	0	0	0	0
14	18	0	2.5	0	0	0	0	0	0	0	0	0
15	0	0	0	11	2.5	0	0	0	0	0	0	2.5
16	2.5	0	6.4	0	0	0	0	0	0	0	0	0
17	0	0	0	1.9	0	0	0	0	0	0	0	7.6
18	0	0	0	1.3	0	0	0	0	0	0	0	0
19	2.5	0	0	2.5	0	0	0	0	0	0	0	0
20	1.3	0	3.8	1.3	0	0	0	0	0	4.4	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	2.5
24	3.8	0	0	1.3	0	0	0	0	0	0	0	1.9
25	0	0	0	0	0	0	0	0	0	7.6	2.5	1.3
26	0	18	0	0	0	0	0	0	0	2.5	0	0
27	2.5	0	0	0	0	0	0	0	0	0	2.5	0
28	0	0	0	0	0	0	0	0	0	5.1	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0
30	0		0	0	2.5	0	0	0	0	0	1.3	0
31	1.3		0			0	0	0		0		

Appendix G. Continued.

MAYS - YEAR: 2001

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0	0	5.1	0	0	0	0	0	0	0	0	0
2	0	1.3	0	0	1.3	0	0	0	0	0	0	0
3	0	2.5	2.5	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	17	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	2.5	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0
9	0	6.4	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	2.5	0	0	6.4	0	0
11	2.5	1.3	0	0	0	2.5	0	0	0	0	0	0
12	0	2.5	0	6.4	0	0	0	0	3.8	0	0	0
13	1.3	0	0	0	0	0	0	0	0	0	7.6	0
14	0	0	7.6	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	5.1	0	5.1	0
17	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	6.4	0	0	0	0	0	0	0	0
19	3.8	0	0	0	0	6.4	0	0	0	0	3.8	0
20	0	0	0	0	6.4	0	13	0	0	0	15	0
21	2.5	6.4	0	0	0	0	0	2.5	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0
24	1.3	0	6.4	0	0	0	0	0	0	0	0	0
25	0	1.3	0	0	0	0	0	0	3.8	0	0	0
26	0	0	8.9	0	0	0	0	0	0	0	0	0
27	0	0	0	3.8	0	0	0	0	0	0	1.3	0
28	0	0	0	0	0	0	0	0	0	0	0	0
29	0		0	3.8	0	0	7.6	0	0	14	0	0
30	0		0	0	0	0	0	0	0	0	0	0
31	0		0		0		0	0		0		0

Appendix G. Continued.

MAYS - YEAR: 2002

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	13	2.5	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	5.1	0	0	0	0	0	0	0	0	0	0	0
6	0	0	3.8	0	0	0	0	0	0	0	0	0
7	1.3	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	2.5	0	2.5	0	0	0	0	0	0
10	0	0	0	5.1	1.3	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	15	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	2.5	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	3.8	0	0	0	0	0	0
18	1.3	3.8	0	0	0	0	0	0	0	0	0	0
19	1.3	0	0	0	3.8	0	0	0	0	0	0	0
20	1.3	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	1.3	0	0	0	0	0	0
23	2.5	0	0	0	0	0	0	0	0	0	0	0
24	5.1	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	20	0	0	0	0	0	0
27	0	0	0	0	0	5.1	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0
29	0		0	0	0	0	0	0	0	0	0	0
30	0		0	0	0	0	0	0	0	0	0	0
31	0		0		0		0	0		0		0

Appendix H. Compiled vegetation data.

	Watershed	Year	Aspect	BARE SOIL	
1	Jensen	1995	East	21.6	
6	Jensen	1995	East	44.1	32.85
1	Jensen	2003	East	1.2	
6	Jensen	2003	East	0	0.6
4	Jensen	1995	North	50.66667	
5	Jensen	1995	North	29.66667	40.16667
4	Jensen	2003	North	0.766667	
5	Jensen	2003	North	21.46667	11.11667
3	Jensen	1995	South	54.6	
8	Jensen	1995	South	48.33333	51.46667
3	Jensen	2003	South	0	
8	Jensen	2003	South	0	0
2	Jensen	1995	West	39.13333	
7	Jensen	1995	West	55.13333	47.13333
2	Jensen	2003	West	0	
7	Jensen	2003	West	0	0
5	Mays	1995	East	43.4	
7	Mays	1995	East	52.86667	48.13333
5	Mays	2003	East	0	
7	Mays	2003	East	0	0
2	Mays	1995	North	45.03333	
6	Mays	1995	North	69.6	57.31667
2	Mays	2003	North	0	
6	Mays	2003	North	0	0
1	Mays	1995	South	50.46667	
8	Mays	1995	South	59.93333	55.2
1	Mays	2003	South	0	
8	Mays	2003	South	0	0
3	Mays	1995	West	39.76667	
4	Mays	1995	West	20.93333	30.35
3	Mays	2003	West	0	
4	Mays	2003	West	0	0

Appendix H. Compiled Vegetation data continued.

	Watershed	Year	Aspect	SHRUBS (DEAD)	
1	Jensen	1995	East	0.933333	
6	Jensen	1995	East	5.866667	3.4
1	Jensen	2003	East	0.733333	
6	Jensen	2003	East	4.8	2.766667
4	Jensen	1995	North	6.4	
5	Jensen	1995	North	8.533333	7.466667
4	Jensen	2003	North	3.333333	
5	Jensen	2003	North	8.9	6.116667
3	Jensen	1995	South	4.233333	
8	Jensen	1995	South	7.533333	5.883333
3	Jensen	2003	South	2.833333	
8	Jensen	2003	South	2	2.416667
2	Jensen	1995	West	8	
7	Jensen	1995	West	11.5	9.75
2	Jensen	2003	West	5.9	
7	Jensen	2003	West	5.9	5.9
5	Mays	1995	East	1.666667	
7	Mays	1995	East	1.966667	1.816667
5	Mays	2003	East	3.6	
7	Mays	2003	East	0.133333	1.866667
2	Mays	1995	North	4.1	
6	Mays	1995	North	0.133333	2.116667
2	Mays	2003	North	1.333333	
6	Mays	2003	North	6.033333	3.683333
1	Mays	1995	South	1.066667	
8	Mays	1995	South	4.266667	2.666667
1	Mays	2003	South	0	
8	Mays	2003	South	2.033333	1.016667
3	Mays	1995	West	4.9	
4	Mays	1995	West	1.566667	3.233333
3	Mays	2003	West	0.1	
4	Mays	2003	West	0.266667	0.183333

Appendix H. Compiled Vegetation data continued.

	Watershed	Year	Aspect	FORBS (PERENNIAL)	
1	Jensen	1995	East	0.7	
6	Jensen	1995	East	1.966667	1.333333
1	Jensen	2003	East	1	
6	Jensen	2003	East	0.966667	0.983333
4	Jensen	1995	North	10.66667	
5	Jensen	1995	North	2.9	6.783333
4	Jensen	2003	North	8.1	
5	Jensen	2003	North	1.133333	4.616667
3	Jensen	1995	South	0.533333	
8	Jensen	1995	South	0	0.266667
3	Jensen	2003	South	0.1	
8	Jensen	2003	South	0	0.05
2	Jensen	1995	West	2.2	
7	Jensen	1995	West	5.1	3.65
2	Jensen	2003	West	2.5	
7	Jensen	2003	West	0.866667	1.683333
5	Mays	1995	East	2.733333	
7	Mays	1995	East	1	1.866667
5	Mays	2003	East	3.666667	
7	Mays	2003	East	0.2	1.933333
2	Mays	1995	North	5.1	
6	Mays	1995	North	6.966667	6.033333
2	Mays	2003	North	4.733333	
6	Mays	2003	North	0.833333	2.783333
1	Mays	1995	South	0.1	
8	Mays	1995	South	0	0.05
1	Mays	2003	South	0.266667	
8	Mays	2003	South	0	0.133333
3	Mays	1995	West	2.633333	
4	Mays	1995	West	3.3	2.966667
3	Mays	2003	West	4.233333	
4	Mays	2003	West	2.966667	3.6

Appendix H. Compiled Vegetation data continued.

	Watershed	Year	Aspect	PERENNIAL GRASS	
1	Jensen	1995	East	18.86667	
6	Jensen	1995	East	13.83333	16.35
1	Jensen	2003	East	11.5	
6	Jensen	2003	East	4.7	8.1
4	Jensen	1995	North	24.33333	
5	Jensen	1995	North	21.03333	22.68333
4	Jensen	2003	North	7.1	
5	Jensen	2003	North	10.9	9
3	Jensen	1995	South	11.3	
8	Jensen	1995	South	18.83333	15.06667
3	Jensen	2003	South	5.166667	
8	Jensen	2003	South	19.8	12.48333
2	Jensen	1995	West	33.43333	
7	Jensen	1995	West	9.333333	21.38333
2	Jensen	2003	West	21.8	
7	Jensen	2003	West	4.933333	13.36667
5	Mays	1995	East	13.23333	
7	Mays	1995	East	15.06667	14.15
5	Mays	2003	East	12.26667	
7	Mays	2003	East	7.033333	9.65
2	Mays	1995	North	29.4	
6	Mays	1995	North	12	20.7
2	Mays	2003	North	8.033333	
6	Mays	2003	North	18.43333	13.23333
1	Mays	1995	South	2.9	
8	Mays	1995	South	3.6	3.25
1	Mays	2003	South	2.533333	
8	Mays	2003	South	0.666667	1.6
3	Mays	1995	West	23.36667	
4	Mays	1995	West	11.9	17.63333
3	Mays	2003	West	4.766667	
4	Mays	2003	West	4.766667	4.766667

Appendix H. Compiled Vegetation data continued.

	Watershed	Year	Aspect	LITTER	
1	Jensen	1995	East	49.76667	
6	Jensen	1995	East	39	44.38333
1	Jensen	2003	East	47.3	
6	Jensen	2003	East	21	34.15
4	Jensen	1995	North	17.4	
5	Jensen	1995	North	40.03333	28.71667
4	Jensen	2003	North	15.16667	
5	Jensen	2003	North	13.63333	14.4
3	Jensen	1995	South	29.36667	
8	Jensen	1995	South	34.96667	32.16667
3	Jensen	2003	South	17.63333	
8	Jensen	2003	South	19.03333	18.33333
2	Jensen	1995	West	14.53333	
7	Jensen	1995	West	23.26667	18.9
2	Jensen	2003	West	3.033333	
7	Jensen	2003	West	23.8	13.41667
5	Mays	1995	East	22.2	
7	Mays	1995	East	29.03333	25.61667
5	Mays	2003	East	13.83333	
7	Mays	2003	East	24.23333	19.03333
2	Mays	1995	North	24.33333	
6	Mays	1995	North	9.833333	17.08333
2	Mays	2003	North	24.63333	
6	Mays	2003	North	26	25.31667
1	Mays	1995	South	48	
8	Mays	1995	South	22.96667	35.48333
1	Mays	2003	South	64.93333	
8	Mays	2003	South	24.1	44.51667
3	Mays	1995	West	32.76667	
4	Mays	1995	West	55.93333	44.35
3	Mays	2003	West	12.26667	
4	Mays	2003	West	59.13333	35.7

Appendix H. Compiled Vegetation data continued.

	Watershed	Year	Aspect	SHRUBS (LIVE)	
1	Jensen	1995	East	3.766667	
6	Jensen	1995	East	5.1	4.433333
1	Jensen	2003	East	1.433333	
6	Jensen	2003	East	5.533333	3.483333
4	Jensen	1995	North	6.166667	
5	Jensen	1995	North	5.6	5.883333
4	Jensen	2003	North	3.1	
5	Jensen	2003	North	6.566667	4.833333
3	Jensen	1995	South	0	
8	Jensen	1995	South	0	0
3	Jensen	2003	South	0.433333	
8	Jensen	2003	South	5.566667	3
2	Jensen	1995	West	9.933333	
7	Jensen	1995	West	4	6.966667
2	Jensen	2003	West	16.53333	
7	Jensen	2003	West	4.3	10.41667
5	Mays	1995	East	3.7	
7	Mays	1995	East	4.133333	3.916667
5	Mays	2003	East	3.233333	
7	Mays	2003	East	5.933333	4.583333
2	Mays	1995	North	5.6	
6	Mays	1995	North	2.433333	4.016667
2	Mays	2003	North	7.133333	
6	Mays	2003	North	8.166667	7.65
1	Mays	1995	South	2.3	
8	Mays	1995	South	5.7	4
1	Mays	2003	South	2.033333	
8	Mays	2003	South	7.666667	4.85
3	Mays	1995	West	4.733333	
4	Mays	1995	West	12.2	8.466667
3	Mays	2003	West	3	
4	Mays	2003	West	13.8	8.4

Appendix H. Compiled Vegetation data continued.

	Watershed	Year	Aspect	TREE	
1	Jensen	1995	East	34.16667	
6	Jensen	1995	East	17.5	25.83333
1	Jensen	2003	East	46.5	
6	Jensen	2003	East	6.766667	26.63333
4	Jensen	1995	North	18.66667	
5	Jensen	1995	North	6	12.33333
4	Jensen	2003	North	16.33333	
5	Jensen	2003	North	0.166667	8.25
3	Jensen	1995	South	23.33333	
8	Jensen	1995	South	47.26667	35.3
3	Jensen	2003	South	31.33333	
8	Jensen	2003	South	41.16667	36.25
2	Jensen	1995	West	0.833333	
7	Jensen	1995	West	27	13.91667
2	Jensen	2003	West	0.433333	
7	Jensen	2003	West	25	12.71667
5	Mays	1995	East	8.666667	
7	Mays	1995	East	0	4.333333
5	Mays	2003	East	10.33333	
7	Mays	2003	East	3.333333	6.833333
2	Mays	1995	North	28.23333	
6	Mays	1995	North	14	21.11667
2	Mays	2003	North	25.33333	
6	Mays	2003	North	35.33333	30.33333
1	Mays	1995	South	56	
8	Mays	1995	South	21	38.5
1	Mays	2003	South	55.5	
8	Mays	2003	South	24	39.75
3	Mays	1995	West	28.66667	
4	Mays	1995	West	42.66667	35.66667
3	Mays	2003	West	14.16667	
4	Mays	2003	West	62.83333	38.5

Appendix I1. Vegetation transect data statistical output, bare soil.

Analysis of Variance (Balanced Designs)

Factor	Type	Levels	Values
Watershe	fixed	2	Jensen Mays
Year	fixed	2	1995 2003
Aspect	fixed	4	East North South West

Analysis of Variance for Bare Soi

Source	DF	SS	MS	F	P
Watershe	1	7.3	7.3	0.07	0.789
Year	1	15391.4	15391.4	153.64	0.000
Aspect	3	399.9	133.3	1.33	0.286
Error	26	2604.6	100.2		
Total	31	18403.2			

Means

Watershe	N	Bare Soi
Jensen	16	22.917
Mays	16	23.875

Year	N	Bare Soi
1995	16	45.327
2003	16	1.465

Aspect	N	Bare Soi
East	8	20.396
North	8	27.150
South	8	26.667
West	8	19.371

Kruskal-Wallis Test

Kruskal-Wallis Test on Bare Soi

Watershe	N	Median	Ave Rank	Z
Jensen	16	21.53	17.0	0.30
Mays	16	10.47	16.0	-0.30
Overall	32		16.5	

H = 0.09 DF = 1 P = 0.763
H = 0.10 DF = 1 P = 0.755 (adjusted for ties)

Appendix I1. Vegetation transect data statistical output, bare soil continued.

Two-way Analysis of Variance

Analysis of Variance for Bare Soi

Source	DF	SS	MS	F	P
Aspect	3	399.9	133.3	1.36	0.279
Year	1	15391.4	15391.4	157.04	0.000
Interaction	3	259.7	86.6	0.88	0.464
Error	24	2352.2	98.0		
Total	31	18403.2			

Two-way Analysis of Variance

Analysis of Variance for Bare Soi

Source	DF	SS	MS	F	P
Aspect	3	400	133	0.18	0.909
Watershe	1	7	7	0.01	0.921
Interaction	3	266	89	0.12	0.947
Error	24	17729	739		
Total	31	18403			

Two-way Analysis of Variance

Analysis of Variance for Bare Soi

Source	DF	SS	MS	F	P
Year	1	15391	15391	149.45	0.000
Watershe	1	7	7	0.07	0.791
Interaction	1	121	121	1.17	0.288
Error	28	2884	103		
Total	31	18403			

One-way Analysis of Variance

Analysis of Variance for Bare Soi

Source	DF	SS	MS	F	P
Watershe	1	7	7	0.01	0.914
Error	30	18396	613		
Total	31	18403			

```
                                        Individual 95% CIs For Mean
                                        Based on Pooled StDev
Level       N       Mean      StDev     --------+---------+---------+----
----
Jensen     16      22.92      22.81      (--------------*-------------)
Mays       16      23.87      26.57       (--------------*-------------
-)
                                        --------+---------+---------+----
----
Pooled StDev =     24.76                      16.0      24.0      32.0
```

Appendix I1. Vegetation transect data statistical output, bare soil continued.

One-way Analysis of Variance

```
Analysis of Variance for Bare Soi
Source      DF        SS         MS          F         P
Aspect       3       400        133       0.21     0.890
Error       28     18003        643
Total       31     18403
                                       Individual 95% CIs For Mean
                                       Based on Pooled StDev
Level        N      Mean      StDev   ----------+---------+---------+--
----
East         8     20.40      23.19    (------------*-----------)
North        8     27.15      26.41         (-----------*-----------)
South        8     26.67      28.70         (-----------*-----------)
West         8     19.37      22.64    (-----------*-----------)
                                      ----------+---------+---------+--
----
Pooled StDev =     25.36                       15        30        45
```

One-way Analysis of Variance

```
Analysis of Variance for Bare Soi
Source      DF        SS         MS          F         P
Year         1     15391      15391     153.31     0.000
Error       30      3012        100
Total       31     18403
                                       Individual 95% CIs For Mean
                                       Based on Pooled StDev
Level        N      Mean      StDev   ---+---------+---------+---------
+---
1995        16     45.33      13.12                                   (--
*---)
2003        16      1.46       5.34    (--*--)
                                      ---+---------+---------+---------
+---
Pooled StDev =     10.02                 0        15        30
45
```

Appendix I2. Vegetation transect data statistical output, bare soil.

Two-way Analysis of Variance

Analysis of Variance for (DEAD)

Source	DF	SS	MS	F	P
Watershe	1	91.91	91.91	16.79	0.000
Aspect	3	35.68	11.89	2.17	0.118
Interaction	3	26.94	8.98	1.64	0.206
Error	24	131.39	5.47		
Total	31	285.93			

```
                        Individual 95% CI
Watershe       Mean     -----+---------+---------+---------+------
Jensen         5.46                               (-------*-------)
Mays           2.07      (-------*-------)
                        -----+---------+---------+---------+------
                           1.50      3.00      4.50      6.00
```

```
                        Individual 95% CI
Aspect         Mean     -----+---------+---------+---------+------
East           2.46     (----------*----------)
North          4.85                   (----------*----------)
South          3.00        (----------*----------)
West           4.77                  (-----------*----------)
                        -----+---------+---------+---------+------
                           1.50      3.00      4.50      6.00
```

Analysis of Variance (Balanced Designs)

Factor	Type	Levels	Values
Watershe	fixed	2	Jensen Mays
Year	fixed	2	1995 2003
Aspect	fixed	4	East North South West

Analysis of Variance for (DEAD)

Source	DF	SS	MS	F	P
Watershe	1	91.914	91.914	17.17	0.000
Year	1	19.168	19.168	3.58	0.070
Aspect	3	35.677	11.892	2.22	0.109
Error	26	139.168	5.353		
Total	31	285.928			

Appendix I2. Vegetation transect data statistical output, bare soil continued.

Means

Aspect	N	(DEAD)
East	8	2.4625
North	8	4.8458
South	8	2.9958
West	8	4.7667

Year	N	(DEAD)
1995	16	4.5417
2003	16	2.9937

Watershe	N	(DEAD)
Jensen	16	5.4625
Mays	16	2.0729

Two-way Analysis of Variance

Analysis of Variance for (DEAD)

Source	DF	SS	MS	F	P
Year	1	19.17	19.17	2.16	0.155
Aspect	3	35.68	11.89	1.34	0.285
Interaction	3	17.92	5.97	0.67	0.577
Error	24	213.16	8.88		
Total	31	285.93			

```
                      Individual 95% CI
Year          Mean    --------+---------+---------+---------+---
1995          4.54                 (------------*------------)
2003          2.99    (------------*------------)
                      --------+---------+---------+---------+---
                            2.40      3.60      4.80      6.00
```

```
                      Individual 95% CI
Aspect        Mean    ---------+---------+---------+---------+--
East          2.46    (----------*----------)
North         4.85                (----------*----------)
South         3.00       (----------*----------)
West          4.77                (----------*----------)
                      ---------+---------+---------+---------+--
                            2.00      4.00      6.00      8.00
```

Appendix I2. Vegetation transect data statistical output, bare soil continued.

Two-way Analysis of Variance

Analysis of Variance for (DEAD)

Source	DF	SS	MS	F	P
Year	1	19.17	19.17	3.16	0.086
Watershe	1	91.91	91.91	15.14	0.001
Interaction	1	4.83	4.83	0.80	0.380
Error	28	170.01	6.07		
Total	31	285.93			

```
                          Individual 95% CI
Year            Mean   ---+---------+---------+---------+--------
1995            4.54                (-----------*------------)
2003            2.99   (------------*------------)
                       ---+---------+---------+---------+--------
                        2.00      3.00      4.00      5.00

                          Individual 95% CI
Watershe        Mean   -----+---------+---------+---------+------
Jensen          5.46                           (-------*--------)
Mays            2.07   (--------*-------)
                       -----+---------+---------+---------+------
                          1.50      3.00      4.50      6.00
```

One-way Analysis of Variance

Analysis of Variance for (DEAD)

Source	DF	SS	MS	F	P
Watershe	1	91.91	91.91	14.21	0.001
Error	30	194.01	6.47		
Total	31	285.93			

```
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Level      N     Mean     StDev    -------+---------+---------+-----
----
Jensen    16    5.462     3.034                      (-----*------)
Mays      16    2.073     1.930     (-----*------)
                                   -------+---------+---------+-----
----
Pooled StDev =  2.543                    2.0       4.0       6.0
```

Appendix I3. Vegetation transect data statistical output, dead shrub.

Two-way Analysis of Variance

Analysis of Variance for (DEAD)

Source	DF	SS	MS	F	P
Watershe	1	91.91	91.91	16.79	0.000
Aspect	3	35.68	11.89	2.17	0.118
Interaction	3	26.94	8.98	1.64	0.206
Error	24	131.39	5.47		
Total	31	285.93			

```
                        Individual 95% CI
Watershe        Mean    -----+---------+---------+---------+------
Jensen          5.46                             (-------*-------)
Mays            2.07     (-------*-------)
                        -----+---------+---------+---------+------
                           1.50      3.00      4.50      6.00
```

```
                        Individual 95% CI
Aspect          Mean    -----+---------+---------+---------+------
East            2.46    (----------*----------)
North           4.85                   (----------*-----------)
South           3.00        (----------*----------)
West            4.77                  (-----------*----------)
                        -----+---------+---------+---------+------
                           1.50      3.00      4.50      6.00
```

Analysis of Variance (Balanced Designs)

Factor	Type	Levels	Values
Watershe	fixed	2	Jensen Mays
Year	fixed	2	1995 2003
Aspect	fixed	4	East North South West

Analysis of Variance for (DEAD)

Source	DF	SS	MS	F	P
Watershe	1	91.914	91.914	17.17	0.000
Year	1	19.168	19.168	3.58	0.070
Aspect	3	35.677	11.892	2.22	0.109
Error	26	139.168	5.353		
Total	31	285.928			

Appendix I3. Vegetation transect data statistical output, dead shrub continued.

Means

Aspect	N	(DEAD)
East	8	2.4625
North	8	4.8458
South	8	2.9958
West	8	4.7667

Year	N	(DEAD)
1995	16	4.5417
2003	16	2.9937

Watershe	N	(DEAD)
Jensen	16	5.4625
Mays	16	2.0729

Two-way Analysis of Variance

Analysis of Variance for (DEAD)

Source	DF	SS	MS	F	P
Year	1	19.17	19.17	2.16	0.155
Aspect	3	35.68	11.89	1.34	0.285
Interaction	3	17.92	5.97	0.67	0.577
Error	24	213.16	8.88		
Total	31	285.93			

```
                          Individual 95% CI
Year            Mean     --------+---------+---------+---------+---
1995            4.54                (------------*------------)
2003            2.99     (------------*------------)
                         --------+---------+---------+---------+---
                              2.40      3.60      4.80      6.00

                          Individual 95% CI
Aspect          Mean     ---------+---------+---------+---------+--
East            2.46     (----------*----------)
North           4.85                (----------*----------)
South           3.00        (----------*----------)
West            4.77                (----------*----------)
                         ---------+---------+---------+---------+--
                              2.00      4.00      6.00      8.00
```

Appendix I3. Vegetation transect data statistical output, dead shrub continued.

Two-way Analysis of Variance

```
Analysis of Variance for (DEAD)
Source          DF        SS        MS        F        P
Year             1     19.17     19.17     3.16    0.086
Watershe         1     91.91     91.91    15.14    0.001
Interaction      1      4.83      4.83     0.80    0.380
Error           28    170.01      6.07
Total           31    285.93

                          Individual 95% CI
Year              Mean    ---+---------+---------+---------+--------
1995              4.54                    (-----------*------------)
2003              2.99    (------------*------------)
                          ---+---------+---------+---------+--------
                          2.00      3.00      4.00      5.00

                          Individual 95% CI
Watershe          Mean    -----+---------+---------+---------+------
Jensen            5.46                          (-------*--------)
Mays              2.07    (--------*-------)
                          -----+---------+---------+---------+------
                             1.50      3.00      4.50      6.00
```

One-way Analysis of Variance

```
Analysis of Variance for (DEAD)
Source     DF        SS        MS        F        P
Watershe    1     91.91     91.91    14.21    0.001
Error      30    194.01      6.47
Total      31    285.93
                                       Individual 95% CIs For Mean
                                       Based on Pooled StDev
Level       N      Mean     StDev      -------+---------+---------+-----
----
Jensen     16     5.462     3.034                      (-----*------)
Mays       16     2.073     1.930       (-----*------)
                                       -------+---------+---------+-----
----
Pooled StDev =    2.543                      2.0       4.0       6.0
```

Appendix I4. Vegetation transect data statistical output, forb.

Analysis of Variance (Balanced Designs)

Factor	Type	Levels	Values
Watershe	fixed	2	Jensen Mays
Year	fixed	2	1995 2003
Aspect	fixed	4	East North South West

Analysis of Variance for Forbs

Source	DF	SS	MS	F	P
Watershe	1	0.000	0.000	0.00	1.000
Year	1	6.420	6.420	1.71	0.202
Aspect	3	106.460	35.487	9.48	0.000
Error	26	97.333	3.744		
Total	31	210.213			

Means

Year	N	Forbs
1995	16	2.8688
2003	16	1.9729

Watershe	N	Forbs
Jensen	16	2.4208
Mays	16	2.4208

Aspect	N	Forbs
East	8	1.5292
North	8	5.0542
South	8	0.1250
West	8	2.9750

Two-way Analysis of Variance

Analysis of Variance for Forbs

Source	DF	SS	MS	F	P
Aspect	3	106.46	35.49	8.64	0.000
Watershe	1	0.00	0.00	0.00	1.000
Interaction	3	5.21	1.74	0.42	0.738
Error	24	98.55	4.11		
Total	31	210.21			

Appendix I4. Vegetation transect data statistical output, forb continued.

Two-way Analysis of Variance

Analysis of Variance for Forbs

Source	DF	SS	MS	F	P
Aspect	3	106.46	35.49	9.66	0.000
Year	1	6.42	6.42	1.75	0.199
Interaction	3	9.19	3.06	0.83	0.488
Error	24	88.15	3.67		
Total	31	210.21			

Two-way Analysis of Variance

Analysis of Variance for Forbs

Source	DF	SS	MS	F	P
Watershe	1	0.00	0.00	0.00	1.000
Year	1	6.42	6.42	0.88	0.355
Interaction	1	0.62	0.62	0.09	0.772
Error	28	203.17	7.26		
Total	31	210.21			

One-way Analysis of Variance

Analysis of Variance for Forbs

Source	DF	SS	MS	F	P
Watershe	1	0.00	0.00	0.00	1.000
Error	30	210.21	7.01		
Total	31	210.21			

```
                                          Individual 95% CIs For Mean
                                          Based on Pooled StDev
Level       N      Mean      StDev   -------+---------+---------+-----
----
Jensen     16     2.421      3.052   (---------------*---------------
-)
Mays       16     2.421      2.167   (---------------*---------------
-)
                                     -------+---------+---------+-----
----
Pooled StDev =    2.647                   1.60      2.40      3.20
```

Appendix I4. Vegetation transect data statistical output, forb continued.

One-way Analysis of Variance

```
Analysis of Variance for Forbs
Source     DF        SS         MS         F        P
Aspect      3    106.46      35.49      9.58    0.000
Error      28    103.75       3.71
Total      31    210.21
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Level       N      Mean      StDev  ------+---------+---------+------
---+
East        8     1.529      1.167         (----*-----)
North       8     5.054      3.430                       (----*-----)
South       8     0.125      0.189  (-----*----)
West        8     2.975      1.287               (-----*----)
                                    ------+---------+---------+------
---+
Pooled StDev =    1.925                  0.0       2.5       5.0
7.5
```

Appendix I5. Vegetation transect data statistical output, perennial grass.

Analysis of Variance (Balanced Designs)

Factor	Type	Levels	Values
Watershe	fixed	2	Jensen Mays
Year	fixed	2	1995 2003
Aspect	fixed	4	East North South West

Analysis of Variance for GRASS

Source	DF	SS	MS	F	P
Watershe	1	139.86	139.86	2.94	0.098
Year	1	435.37	435.37	9.15	0.006
Aspect	3	302.45	100.82	2.12	0.122
Error	26	1237.03	47.58		
Total	31	2114.72			

Means

Watershe	N	GRASS
Jensen	16	14.804
Mays	16	10.623

Year	N	GRASS
1995	16	16.402
2003	16	9.025

Aspect	N	GRASS
East	8	12.063
North	8	16.404
South	8	8.100
West	8	14.288

Two-way Analysis of Variance

Analysis of Variance for GRASS

Source	DF	SS	MS	F	P
Aspect	3	302.5	100.8	1.64	0.207
Watershe	1	139.9	139.9	2.27	0.145
Interaction	3	196.8	65.6	1.07	0.382
Error	24	1475.6	61.5		
Total	31	2114.7			

Appendix I5. Vegetation transect data statistical output, perennial grass continued.

Two-way Analysis of Variance

Analysis of Variance for GRASS

Source	DF	SS	MS	F	P
Aspect	3	302.5	100.8	1.89	0.158
Year	1	435.4	435.4	8.16	0.009
Interaction	3	96.6	32.2	0.60	0.619
Error	24	1280.3	53.3		
Total	31	2114.7			

Two-way Analysis of Variance

Analysis of Variance for GRASS

Source	DF	SS	MS	F	P
Watershe	1	139.9	139.9	2.55	0.121
Year	1	435.4	435.4	7.94	0.009
Interaction	1	4.6	4.6	0.08	0.775
Error	28	1534.9	54.8		
Total	31	2114.7			

One-way Analysis of Variance

Analysis of Variance for GRASS

Source	DF	SS	MS	F	P
Watershe	1	139.9	139.9	2.12	0.155
Error	30	1974.9	65.8		
Total	31	2114.7			

```
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level         N      Mean     StDev  --+---------+---------+---------+----
Jensen       16    14.804     8.183            (-----------*-----------)
Mays         16    10.623     8.044   (----------*-----------)
                                     --+---------+---------+---------+----
Pooled StDev =      8.113              7.0      10.5      14.0      17.5
```

Appendix I5. Vegetation transect data statistical output, perennial grass continued.

One-way Analysis of Variance

Analysis of Variance for GRASS

Source	DF	SS	MS	F	P
Aspect	3	302.5	100.8	1.56	0.222
Error	28	1812.3	64.7		
Total	31	2114.7			

```
                                     Individual 95% CIs For Mean
                                     Based on Pooled StDev
Level      N     Mean     StDev  -------+---------+---------+---------
East       8   12.063     4.467          (---------*---------)
North      8   16.404     8.138                  (---------*---------)
South      8    8.100     7.601   (---------*---------)
West       8   14.288    10.720              (---------*---------)
                                 -------+---------+---------+---------
Pooled StDev =  8.045                  6.0      12.0      18.0
```

Appendix I6. Vegetation transect data statistical output, perennial grass.

Analysis of Variance (Balanced Designs)

Factor	Type	Levels	Values
Watershe	fixed	2	Jensen Mays
Year	fixed	2	1995 2003
Aspect	fixed	4	East North South West

Analysis of Variance for Litter

Source	DF	SS	MS	F	P
Watershe	1	227.2	227.2	0.96	0.335
Year	1	218.8	218.8	0.93	0.344
Aspect	3	582.8	194.3	0.82	0.493
Error	26	6130.0	235.8		
Total	31	7158.8			

Means

Watershe	N	Litter
Jensen	16	25.558
Mays	16	30.887

Year	N	Litter
1995	16	30.838
2003	16	25.608

Aspect	N	Litter
East	8	30.796
North	8	21.379
South	8	32.625
West	8	28.092

Two-way Analysis of Variance

Analysis of Variance for Litter

Source	DF	SS	MS	F	P
Aspect	3	583	194	0.74	0.539
Year	1	219	219	0.83	0.371
Interaction	3	53	18	0.07	0.977
Error	24	6305	263		
Total	31	7159			

Appendix I6. Vegetation transect data statistical output, perennial grass continued.

Two-way Analysis of Variance

Analysis of Variance for Litter

Source	DF	SS	MS	F	P
Aspect	3	583	194	1.05	0.387
Watershe	1	227	227	1.23	0.278
Interaction	3	1921	640	3.47	0.032
Error	24	4427	184		
Total	31	7159			

Two-way Analysis of Variance

Analysis of Variance for Litter

Source	DF	SS	MS	F	P
Year	1	219	219	0.95	0.338
Watershe	1	227	227	0.99	0.329
Interaction	1	263	263	1.14	0.294
Error	28	6449	230		
Total	31	7159			

One-way Analysis of Variance

Analysis of Variance for Litter

Source	DF	SS	MS	F	P
Watershe	1	227	227	0.98	0.329
Error	30	6932	231		
Total	31	7159			

```
                                        Individual 95% CIs For Mean
                                        Based on Pooled StDev
Level        N      Mean      StDev   -+---------+---------+---------+-
----
Jensen      16     25.56      13.25    (------------*------------)
Mays        16     30.89      16.93              (-----------*---------
--)
                                      -+---------+---------+---------+-
----
Pooled StDev =     15.20             18.0      24.0      30.0      36.0
```

Appendix I6. Vegetation transect data statistical output, litter.

Analysis of Variance (Balanced Designs)

Factor	Type	Levels	Values
Watershe	fixed	2	Jensen Mays
Year	fixed	2	1995 2003
Aspect	fixed	4	East North South West

Analysis of Variance for Live Shr

Source	DF	SS	MS	F	P
Watershe	1	5.89	5.89	0.56	0.463
Year	1	11.36	11.36	1.07	0.311
Aspect	3	141.00	47.00	4.43	0.012
Error	26	276.09	10.62		
Total	31	434.35			

Means

Watershe	N	Live Shr
Jensen	16	4.8771
Mays	16	5.7354

Year	N	Live Shr
1995	16	4.7104
2003	16	5.9021

Aspect	N	Live Shr
East	8	4.1042
North	8	5.5958
South	8	2.9625
West	8	8.5625

Two-way Analysis of Variance

Analysis of Variance for Live Shr

Source	DF	SS	MS	F	P
Aspect	3	141.0	47.0	4.07	0.018
Year	1	11.4	11.4	0.98	0.331
Interaction	3	5.2	1.7	0.15	0.929
Error	24	276.8	11.5		
Total	31	434.3			

Appendix I6. Vegetation transect data statistical output, litter continued.

Two-way Analysis of Variance

Analysis of Variance for Live Shr

Source	DF	SS	MS	F	P
Aspect	3	141.0	47.0	4.09	0.018
Watershe	1	5.9	5.9	0.51	0.481
Interaction	3	12.0	4.0	0.35	0.791
Error	24	275.5	11.5		
Total	31	434.3			

Two-way Analysis of Variance

Analysis of Variance for Live Shr

Source	DF	SS	MS	F	P
Year	1	11.4	11.4	0.76	0.390
Watershe	1	5.9	5.9	0.40	0.534
Interaction	1	0.1	0.1	0.00	0.954
Error	28	417.0	14.9		
Total	31	434.3			

One-way Analysis of Variance

Analysis of Variance for Live Shr

Source	DF	SS	MS	F	P
Watershe	1	5.9	5.9	0.41	0.525
Error	30	428.5	14.3		
Total	31	434.3			

```
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level      N      Mean     StDev   -+---------+---------+---------+-
----
Jensen    16     4.877     4.100    (------------*-----------)
Mays      16     5.735     3.429          (------------*------------)
                                   -+---------+---------+---------+-
----
Pooled StDev =   3.779             3.0       4.5       6.0       7.5
```

Appendix I7. Vegetation transect data statistical output, tree.

Analysis of Variance (Balanced Designs)

Factor	Type	Levels	Values
Watershe	fixed	2	Jensen Mays
Year	fixed	2	1995 2003
Aspect	fixed	4	East North South West

Analysis of Variance for Tree

Source	DF	SS	MS	F	P
Watershe	1	239.8	239.8	0.88	0.356
Year	1	18.8	18.8	0.07	0.795
Aspect	3	2269.1	756.4	2.78	0.061
Error	26	7065.4	271.7		
Total	31	9593.1			

Means

Watershe	N	Tree
Jensen	16	21.404
Mays	16	26.879

Year	N	Tree
1995	16	23.375
2003	16	24.908

Aspect	N	Tree
East	8	15.908
North	8	18.008
South	8	37.450
West	8	25.200

Kruskal-Wallis Test

Kruskal-Wallis Test on Tree

Watershe	N	Median	Ave Rank	Z
Jensen	16	21.00	15.3	-0.72
Mays	16	24.67	17.7	0.72
Overall	32		16.5	

H = 0.51 DF = 1 P = 0.474

Appendix I7. Vegetation transect data statistical output, tree continued.

Two-way Analysis of Variance

Analysis of Variance for Tree

Source	DF	SS	MS	F	P
Aspect	3	2269	756	2.49	0.085
Year	1	19	19	0.06	0.806
Interaction	3	4	1	0.00	1.000
Error	24	7302	304		
Total	31	9593			

Two-way Analysis of Variance

Analysis of Variance for Tree

Source	DF	SS	MS	F	P
Aspect	3	2269	756	3.75	0.024
Watershe	1	240	240	1.19	0.286
Interaction	3	2242	747	3.70	0.025
Error	24	4843	202		
Total	31	9593			

Two-way Analysis of Variance

Analysis of Variance for Tree

Source	DF	SS	MS	F	P
Year	1	19	19	0.06	0.814
Watershe	1	240	240	0.72	0.402
Interaction	1	47	47	0.14	0.710
Error	28	9288	332		
Total	31	9593			

One-way Analysis of Variance

Analysis of Variance for Tree

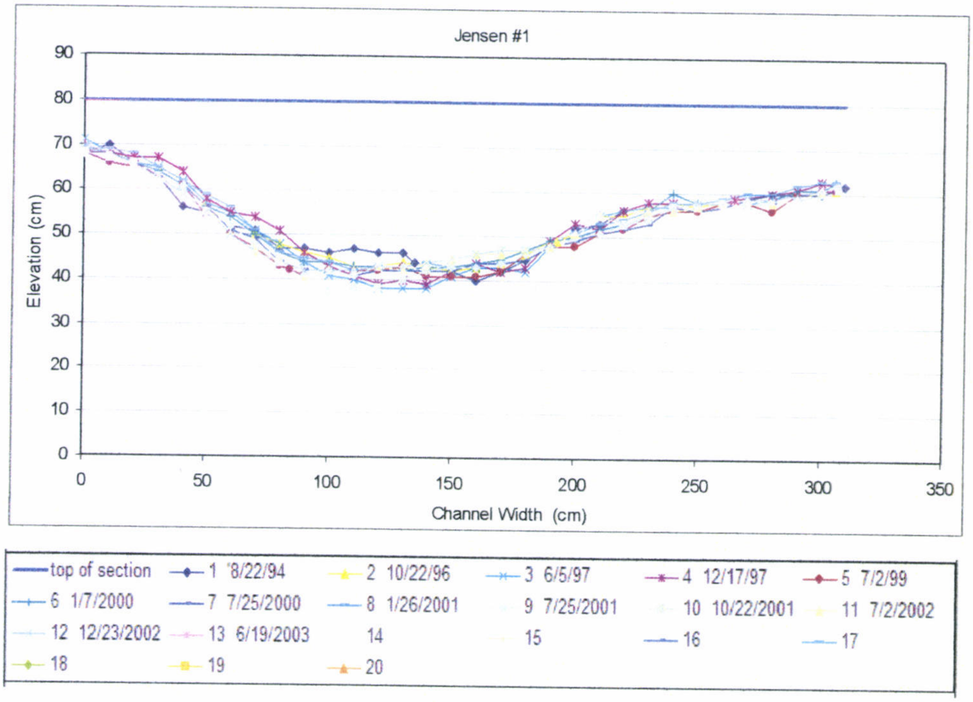
Source	DF	SS	MS	F	P
Watershe	1	240	240	0.77	0.387
Error	30	9353	312		
Total	31	9593			

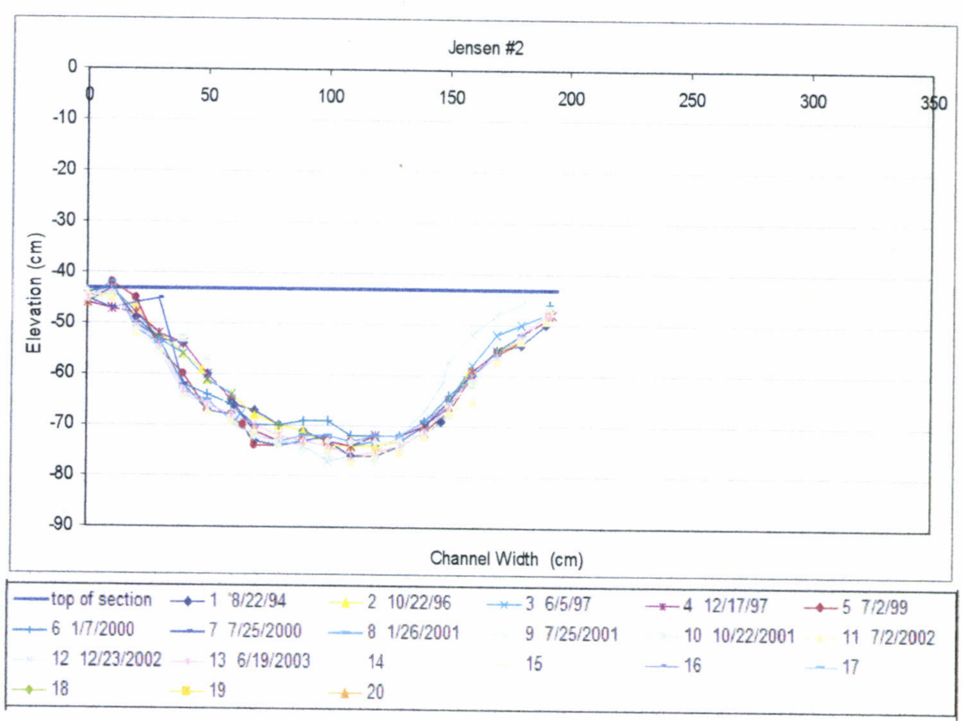
```
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N     Mean     StDev   ---+---------+---------+---------+---
Jensen     16    21.40     15.94    (-----------*-----------)
Mays       16    26.88     19.22           (-----------*-----------)
                                   ---+---------+---------+---------+---
Pooled StDev =    17.66               14.0      21.0      28.0
35.0
```

Appendix I7. Vegetation transect data statistical output, tree continued.

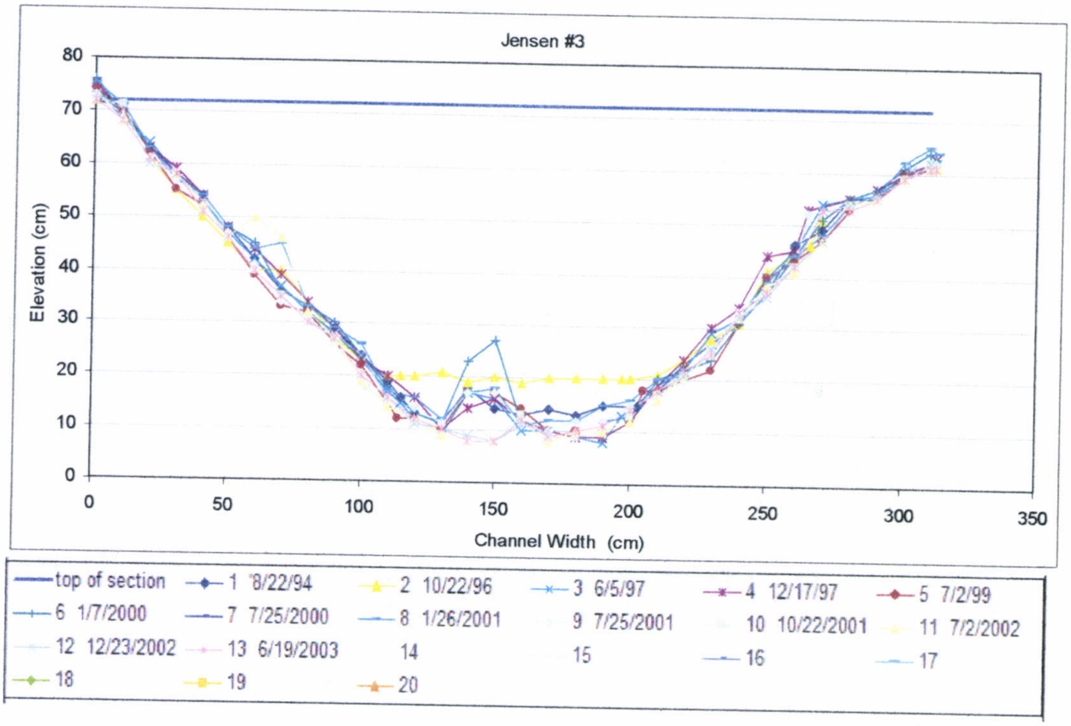
One-way Analysis of Variance

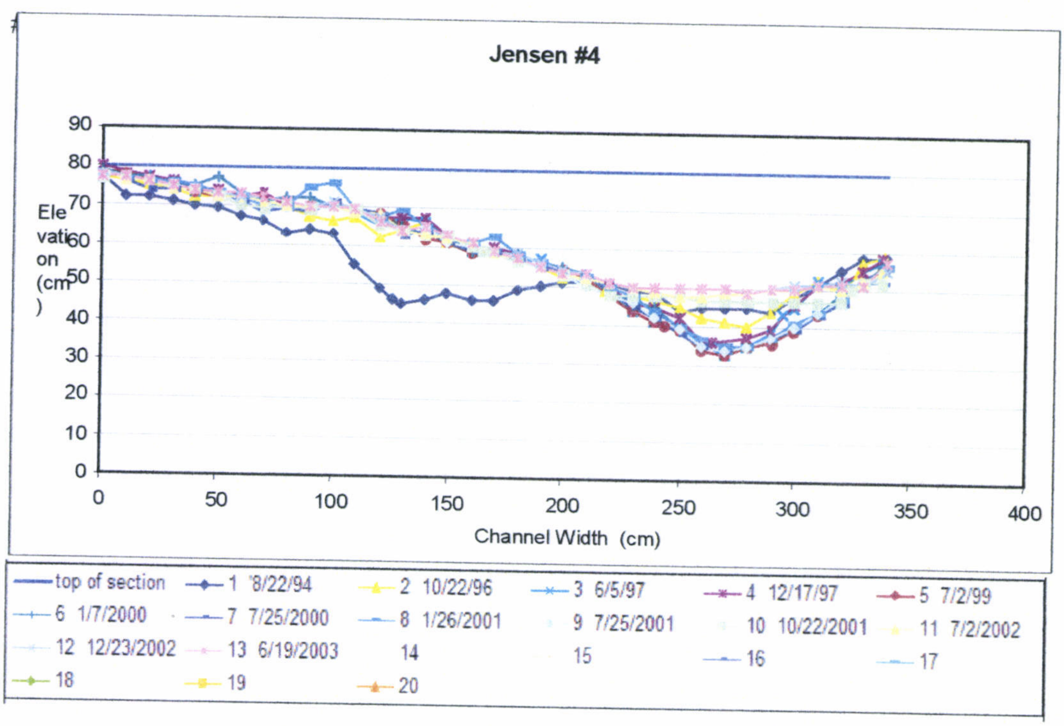
```
Analysis of Variance for Tree
Source      DF        SS        MS        F        P
Aspect       3      2269       756     2.89    0.053
Error       28      7324       262
Total       31      9593
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Level        N      Mean     StDev  --------+---------+---------+----
----
East         8     15.91     16.26   (-------*------)
North        8     18.01     11.59    (-------*-------)
South        8     37.45     14.48              (-------*-------)
West         8     25.20     20.93        (-------*-------)
                                    --------+---------+---------+----
----
Pooled StDev =     16.17                   15        30        45
```





Appendix J. Graphical display of the differences across collection periods of Jensen cross-section plots 1-25 and Mays cross-section plots 1-25.





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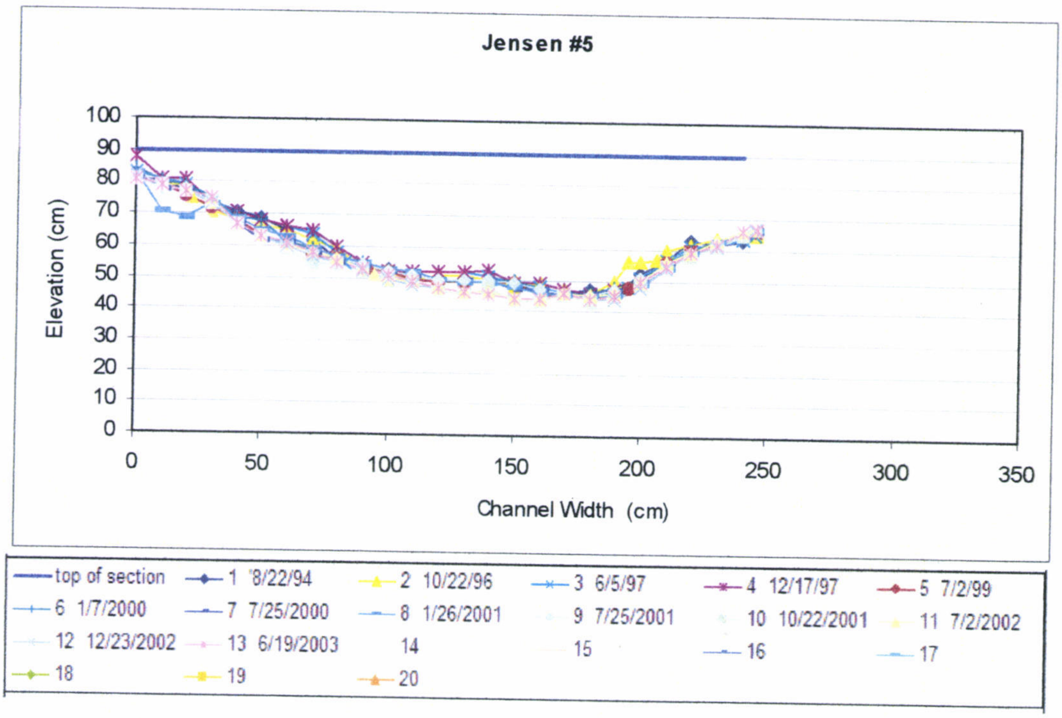

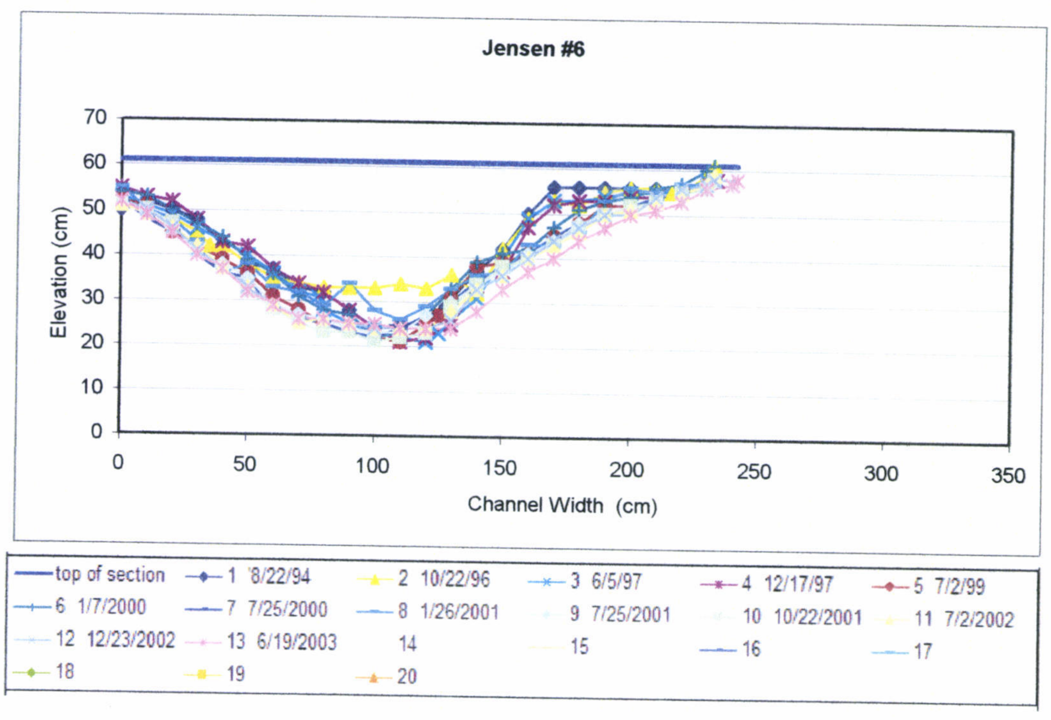

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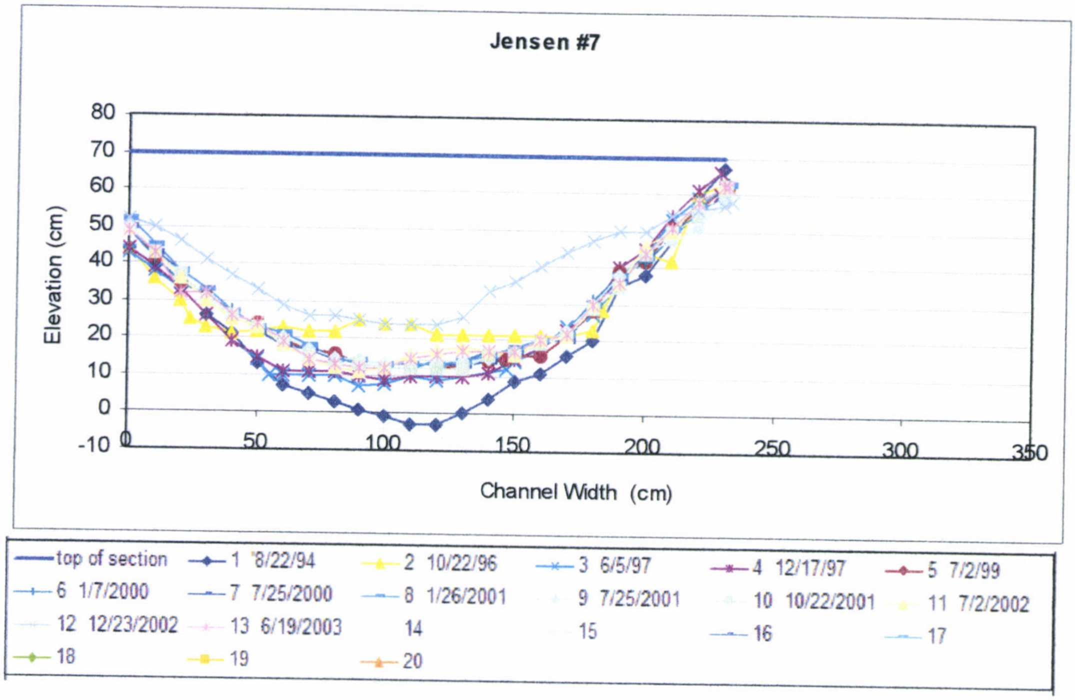

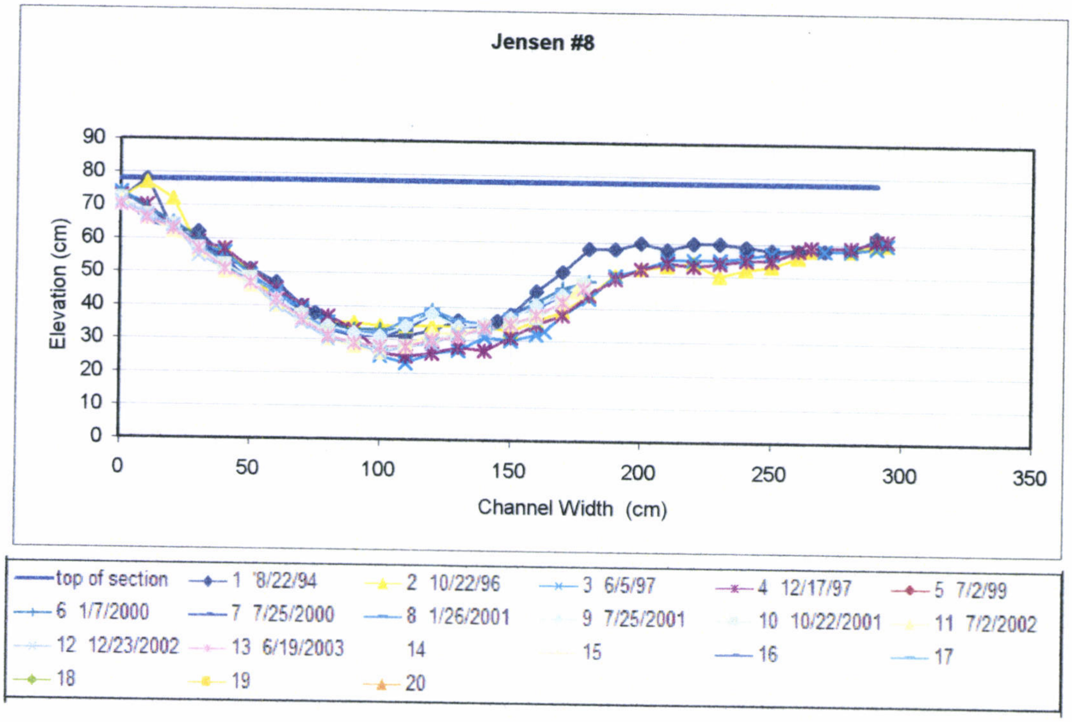

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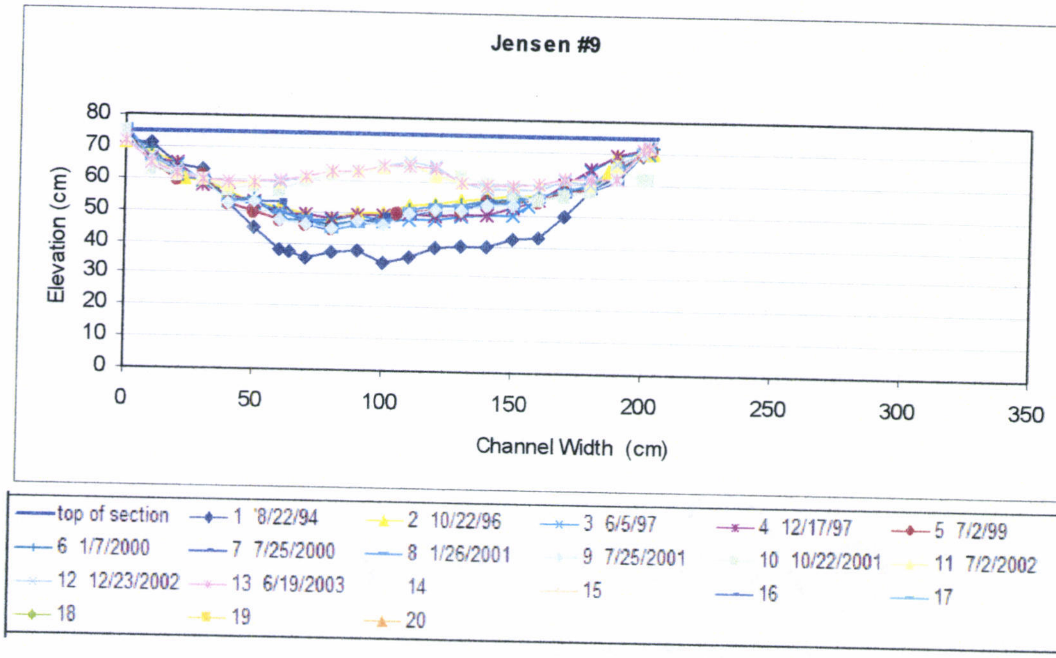

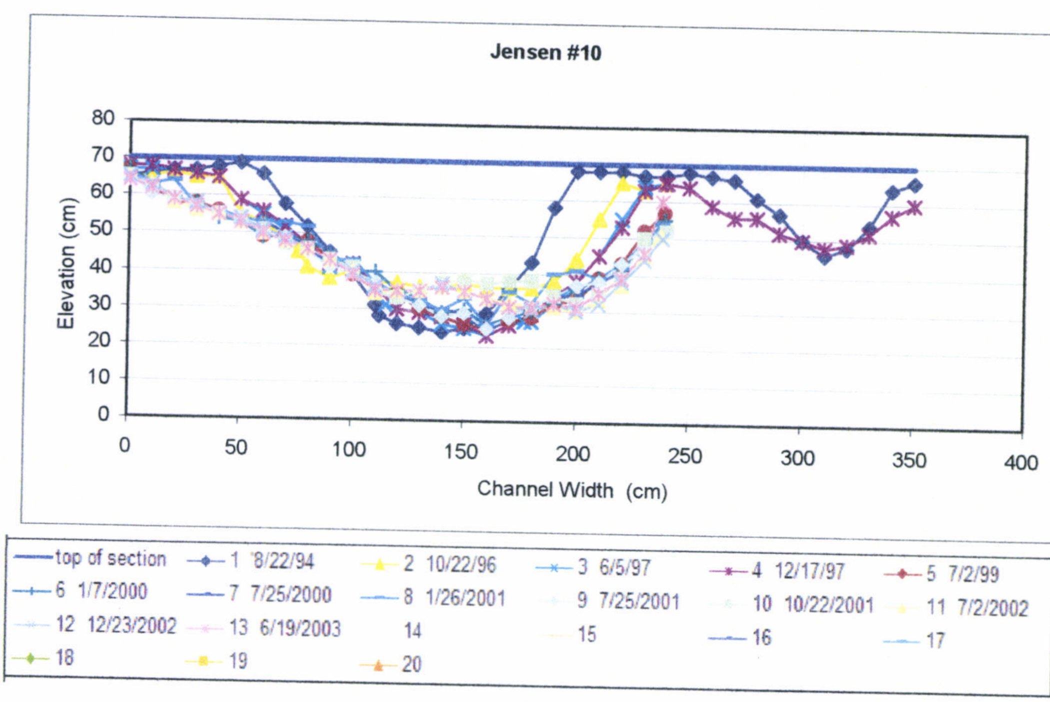

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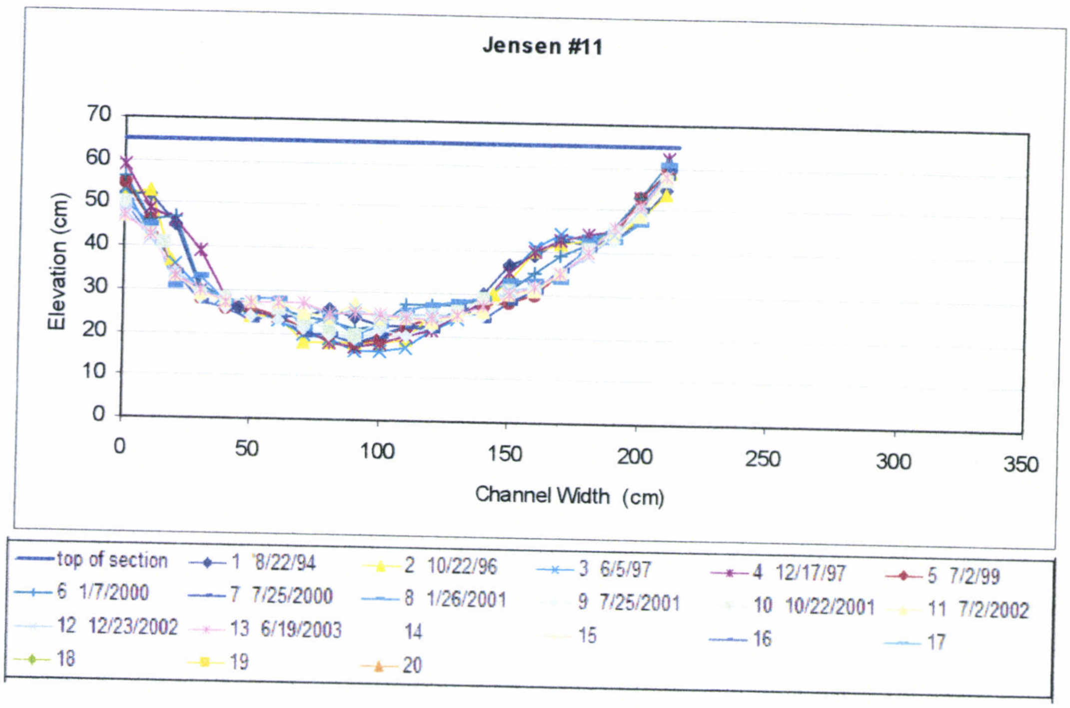

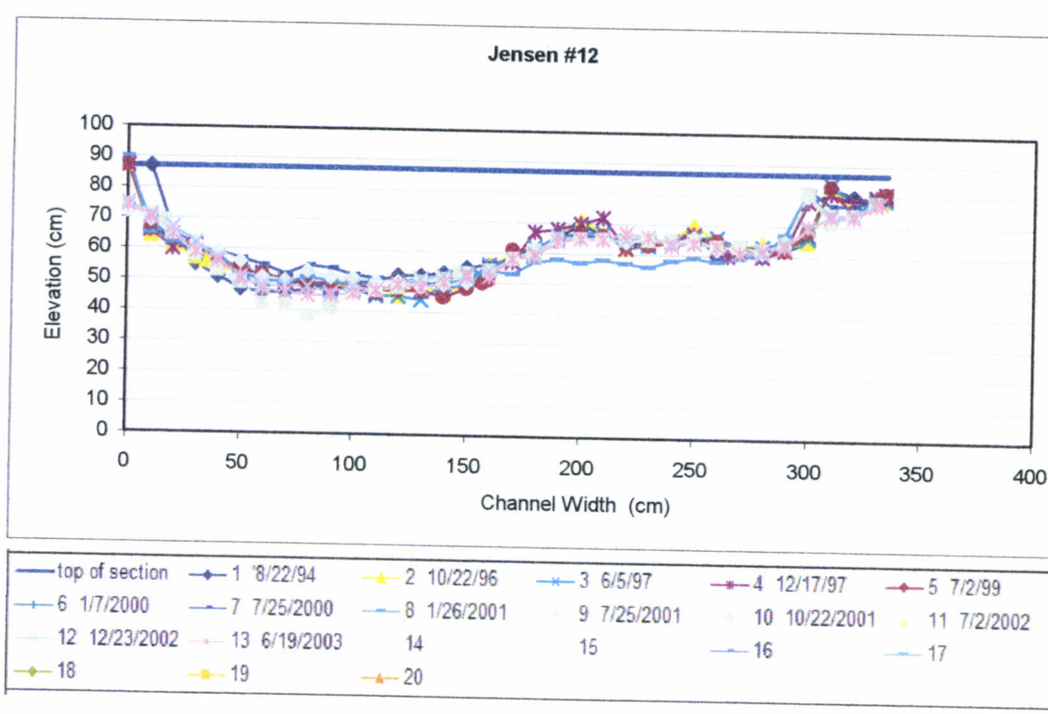

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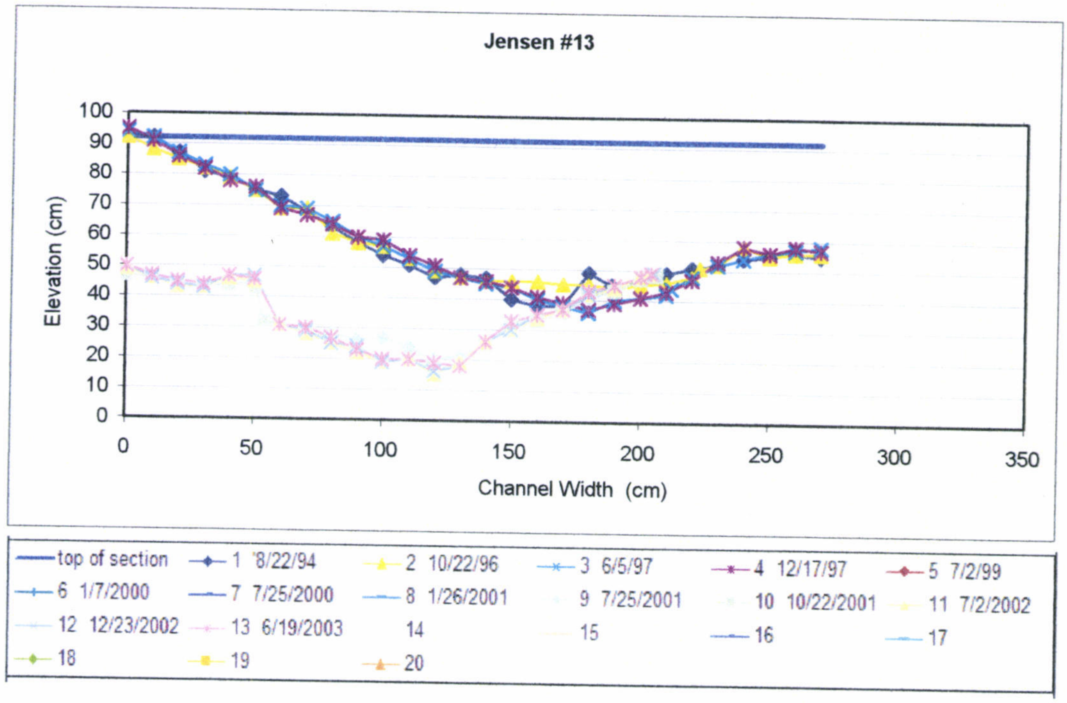

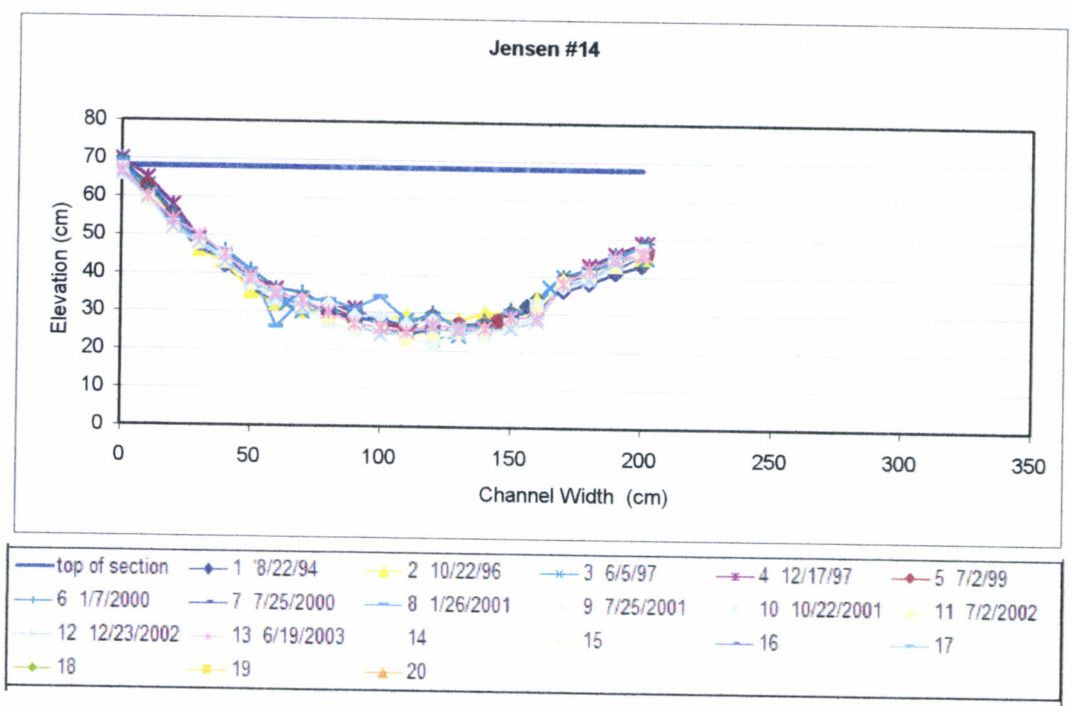

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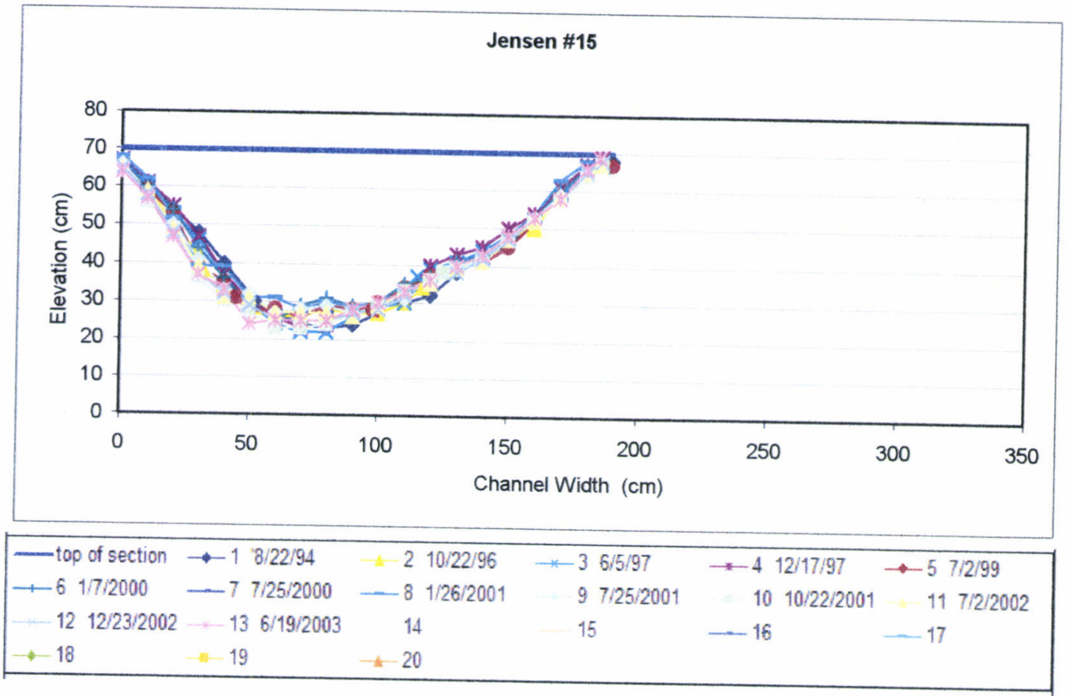

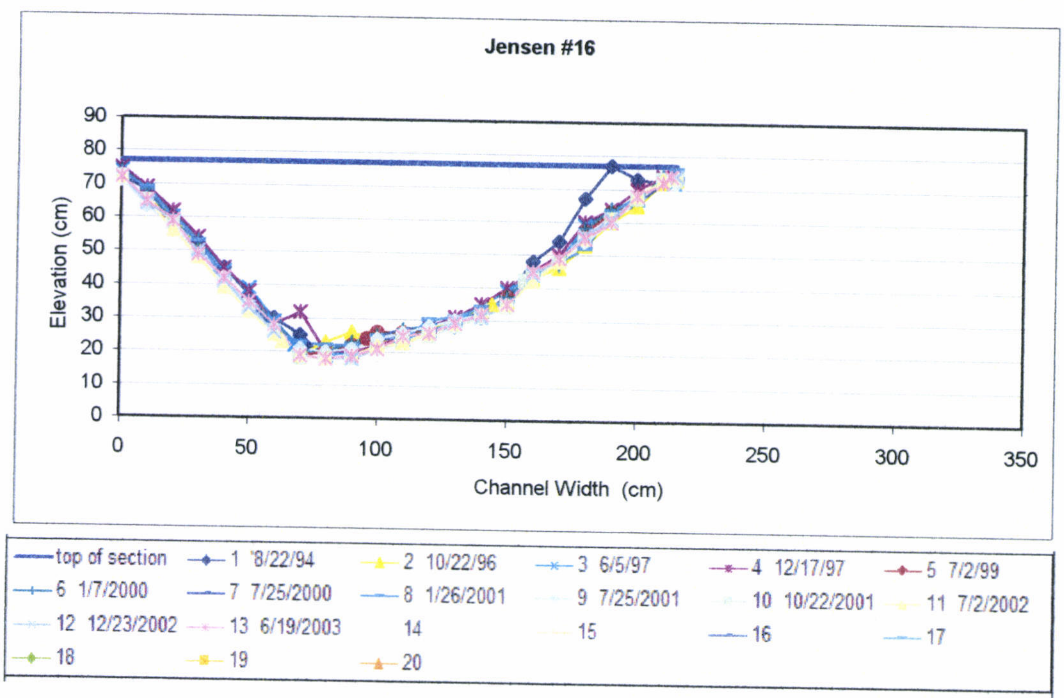

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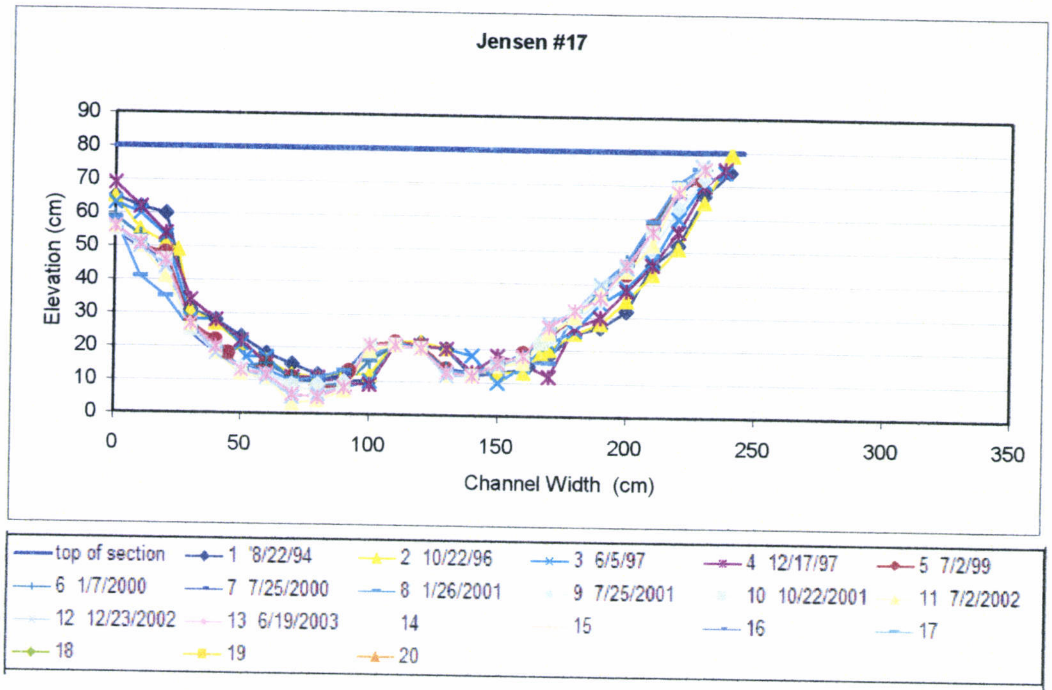

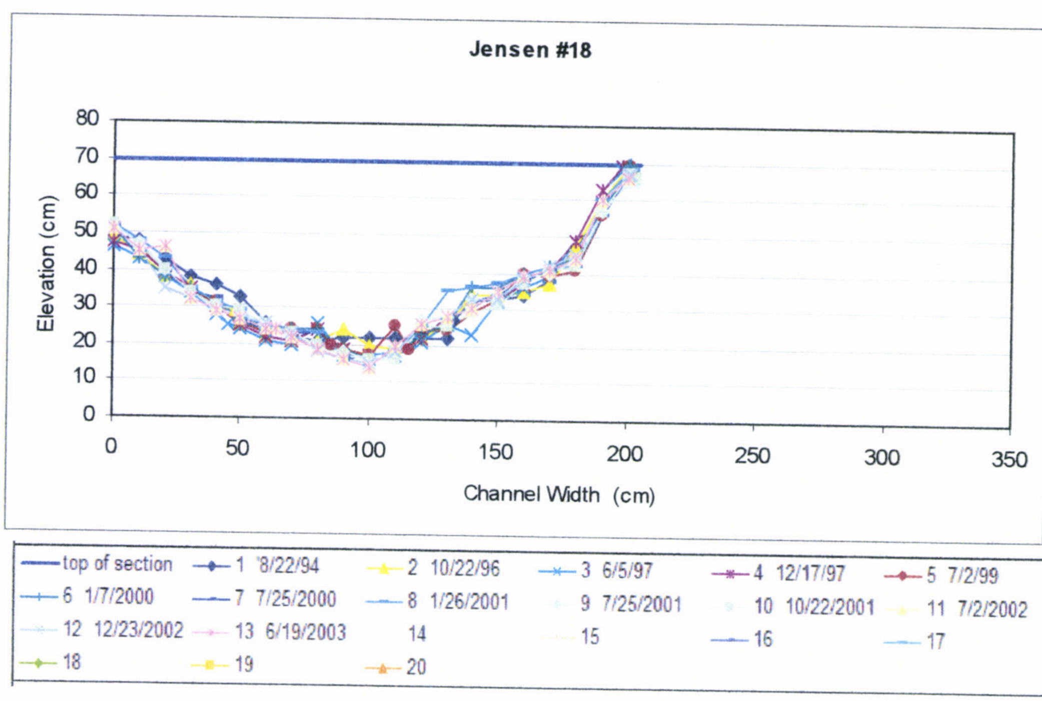

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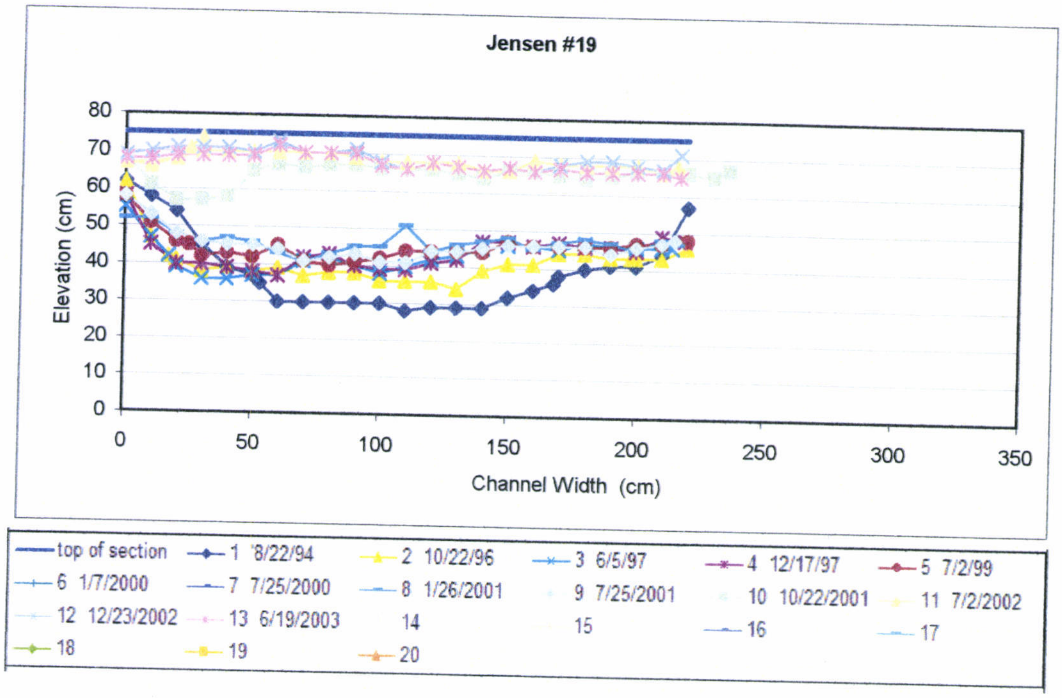

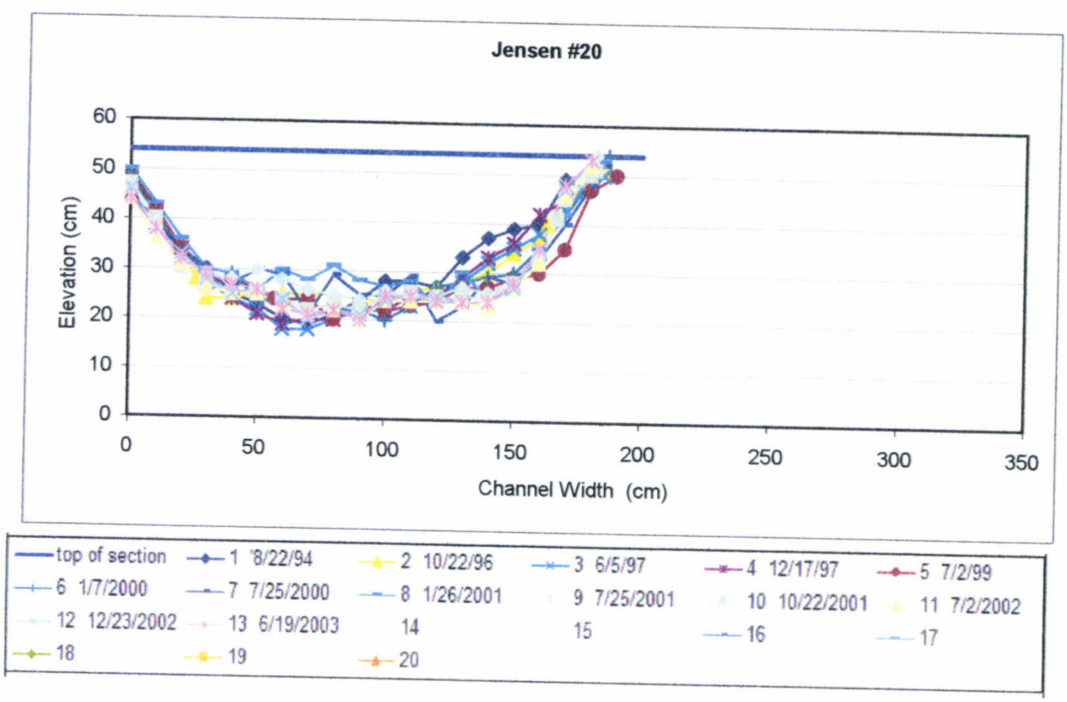

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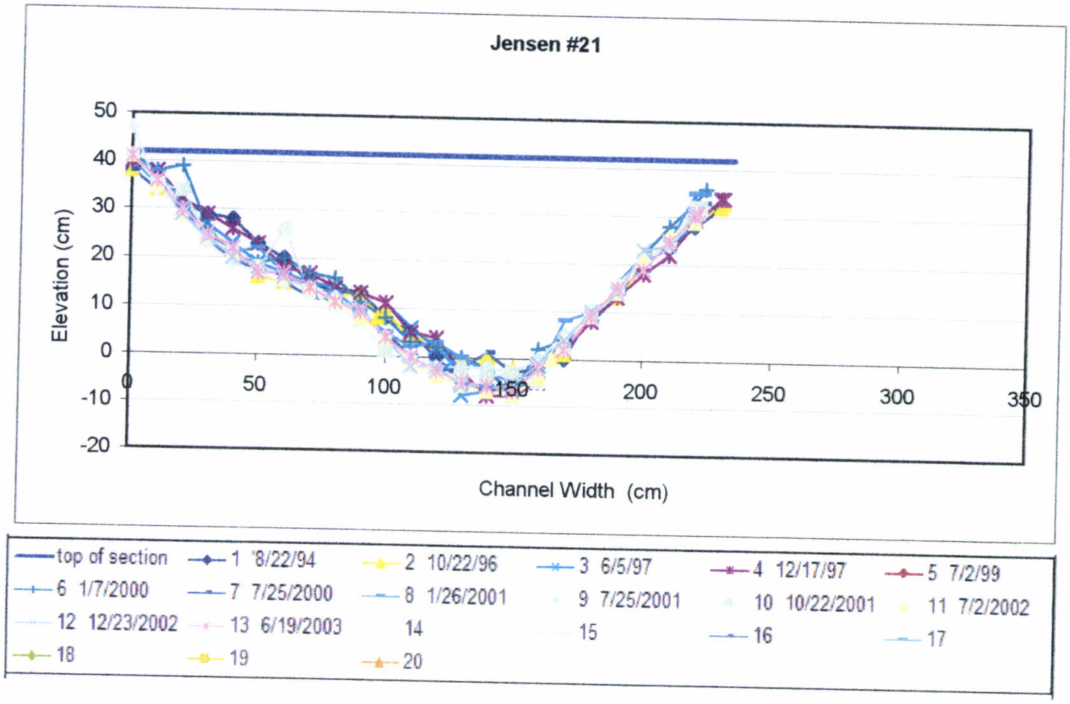

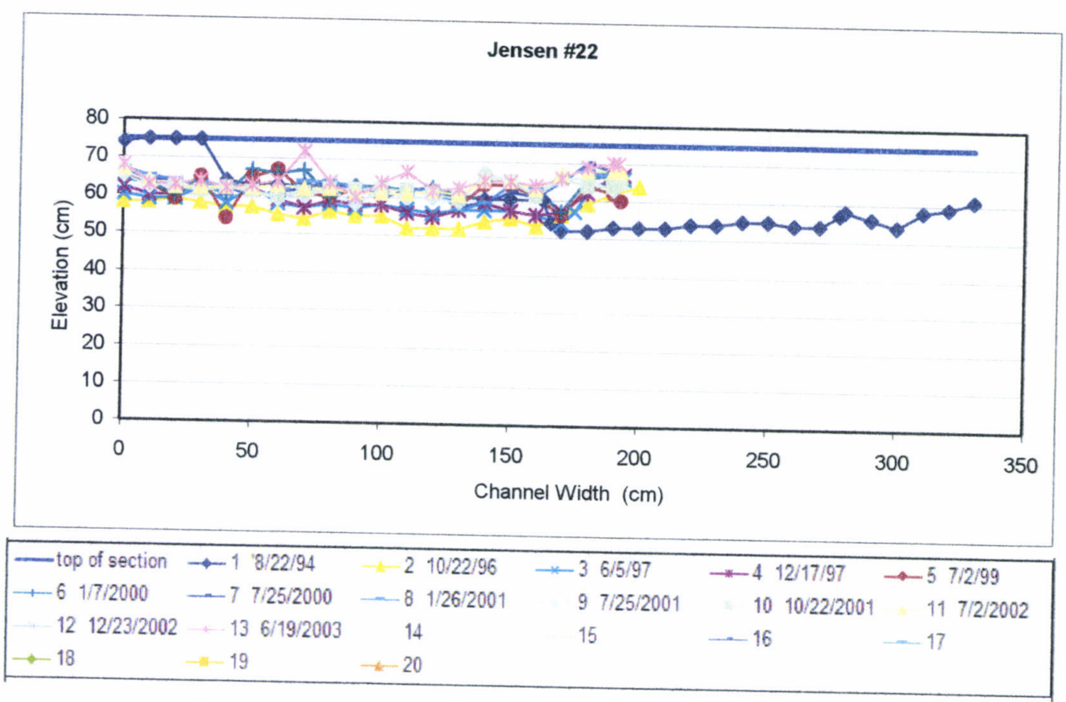

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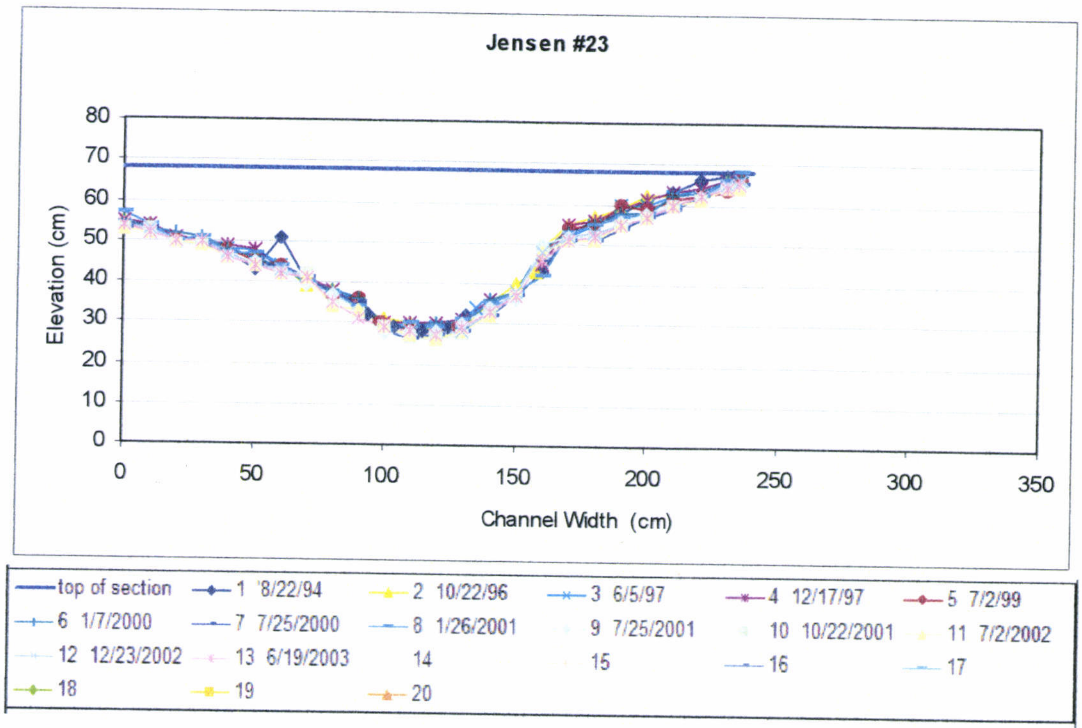

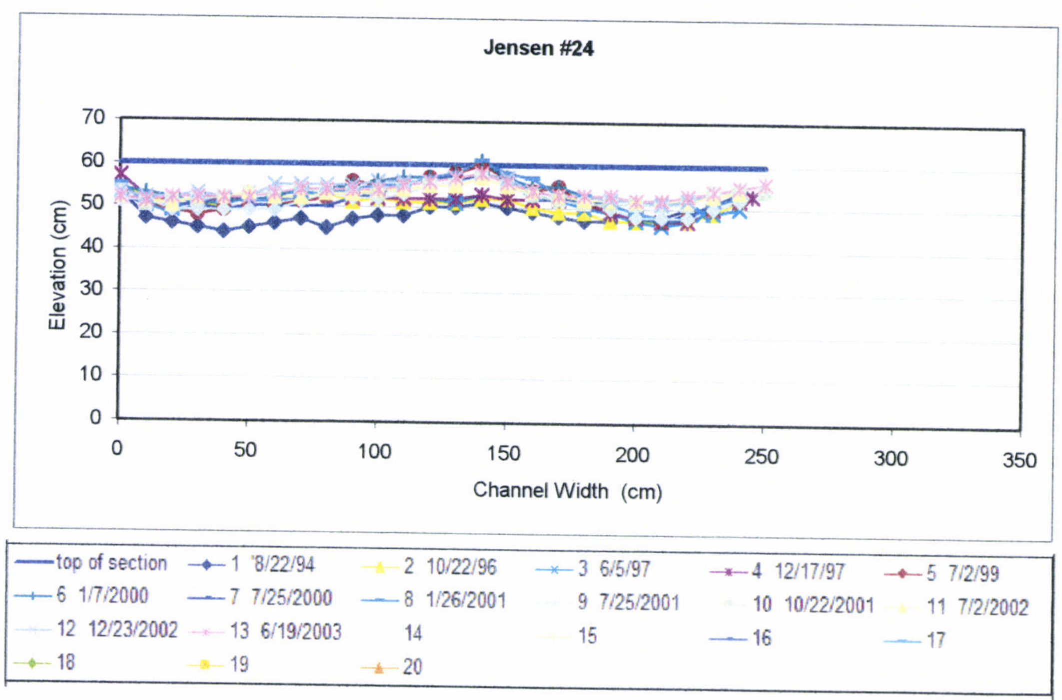

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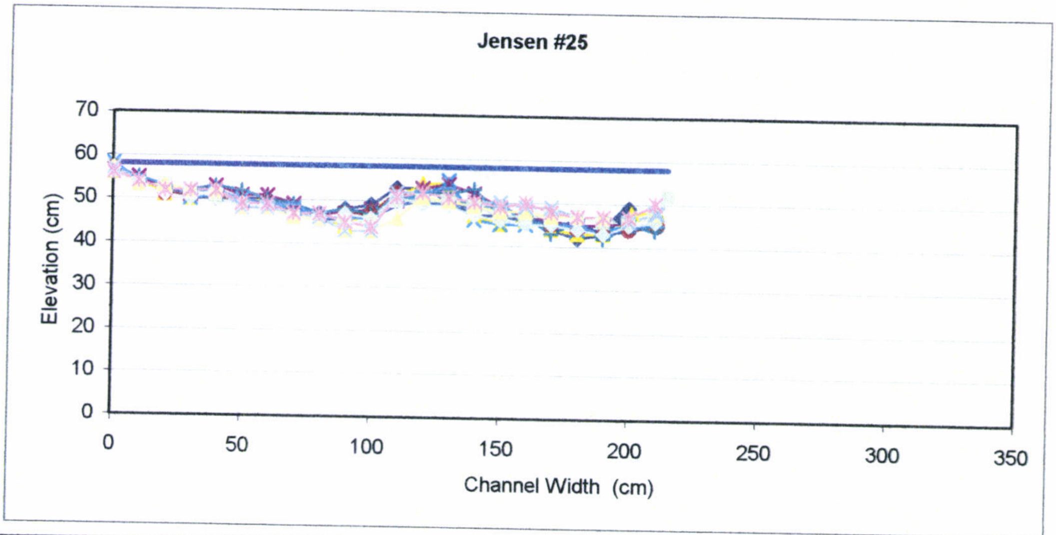

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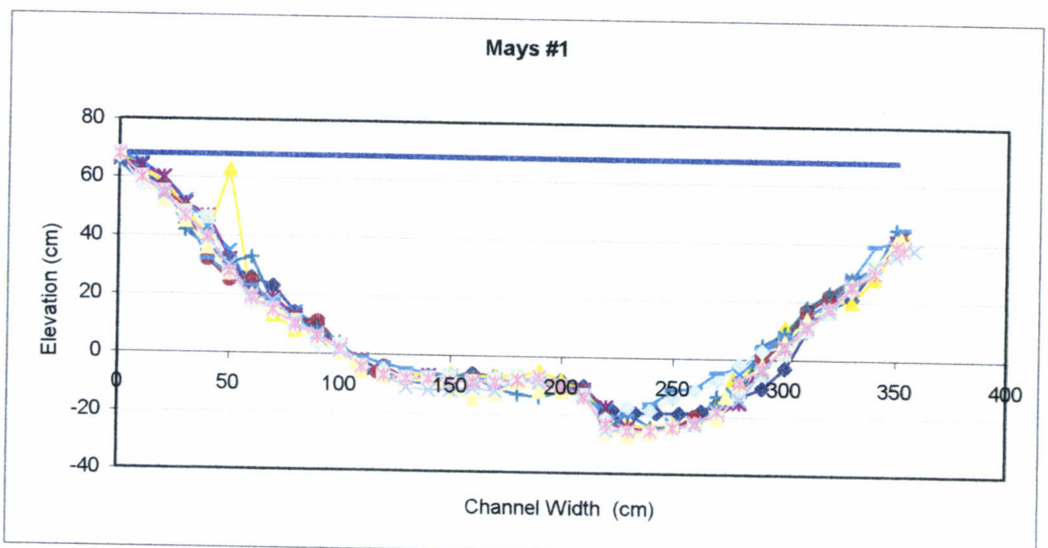

top of section | 1 8/22/94 | 2 10/22/96 | 3 6/5/97 | 4 12/17/97 | 5 7/2/99 | 6 1/7/2000 | 7 7/25/2000 | 8 1/26/2001 | 9 7/25/2001 | 10 10/22/2001 | 11 7/2/2002 | 12 12/23/2002 | 13 6/19/2003 | 14 | 15 | 16 | 17 | 18 | 19 | 20

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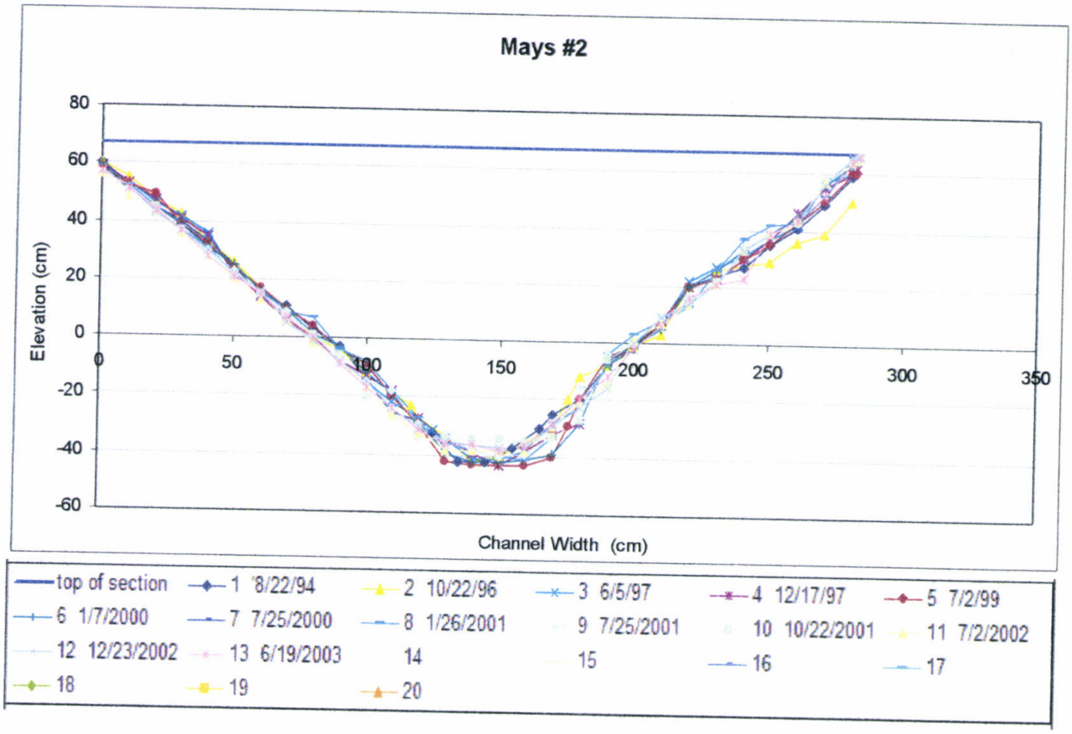

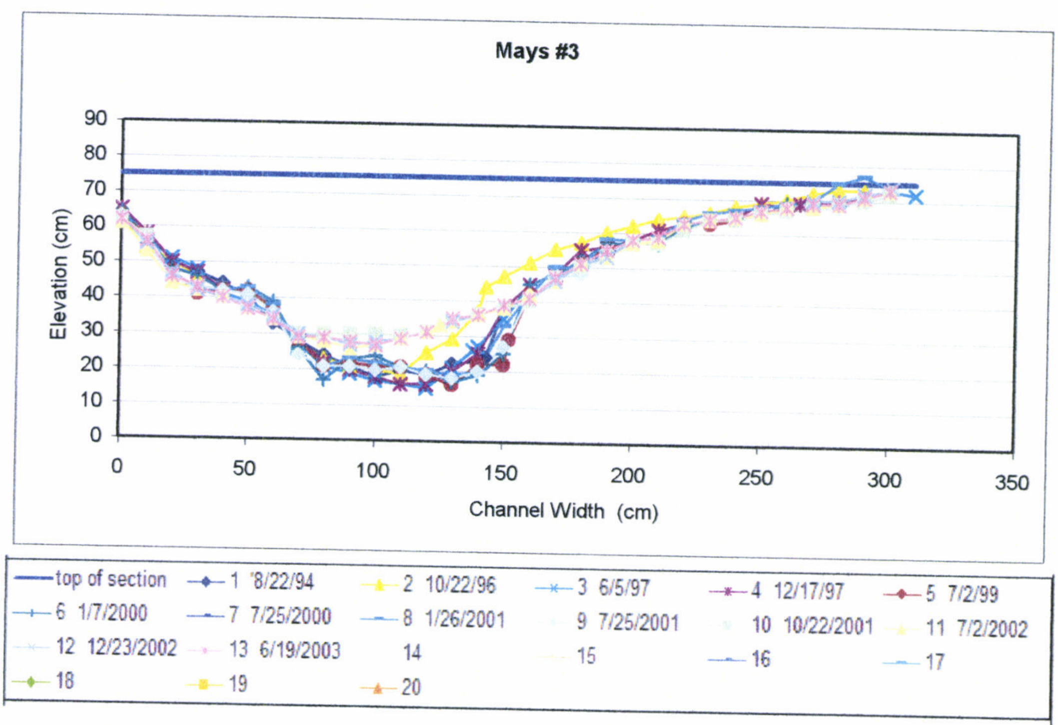

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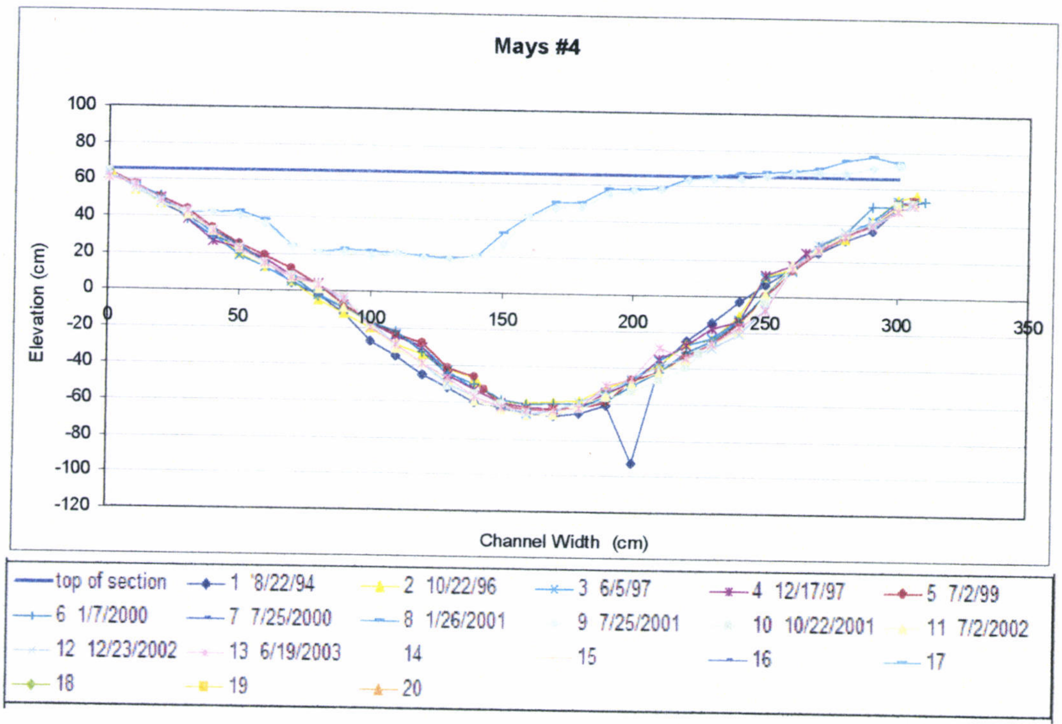

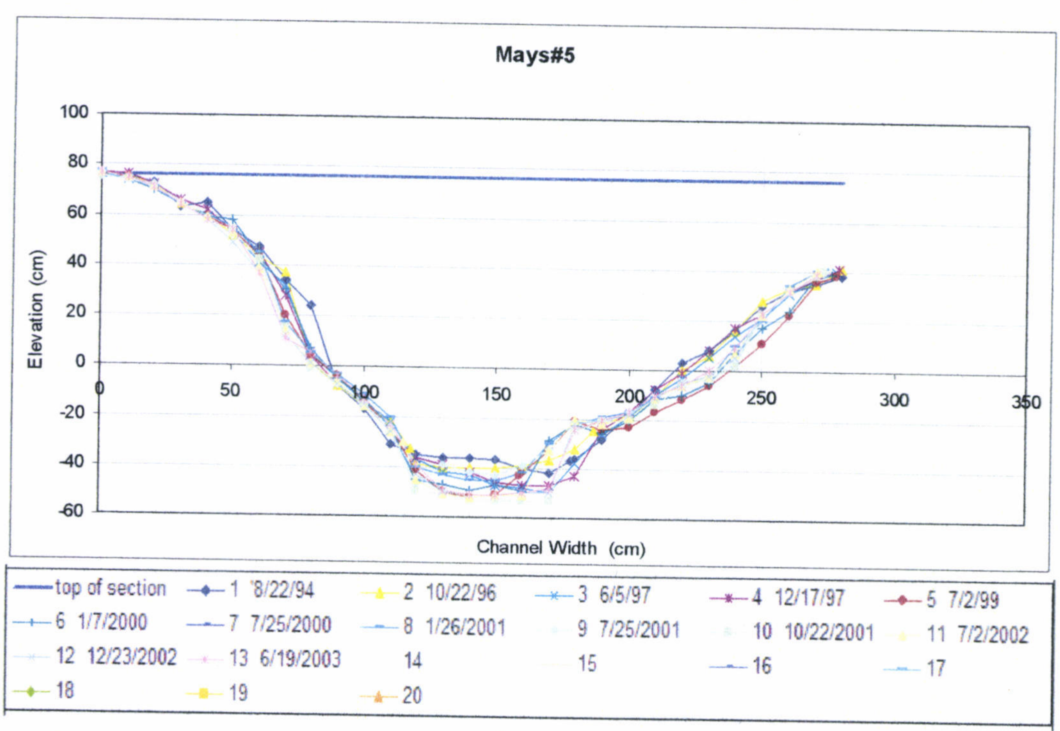

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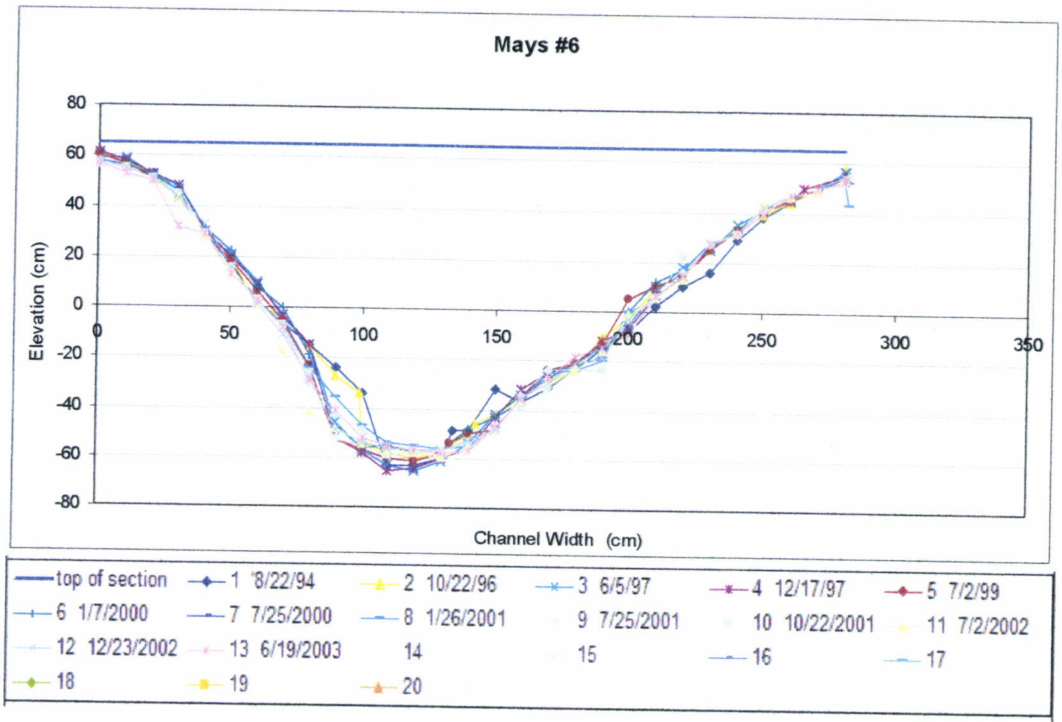

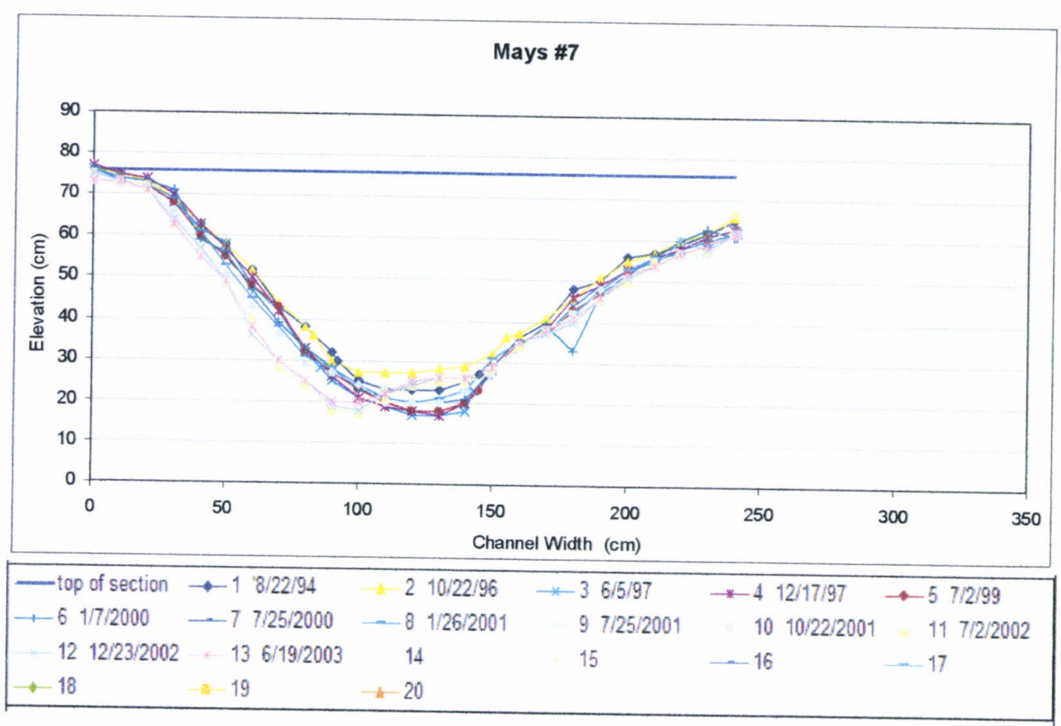

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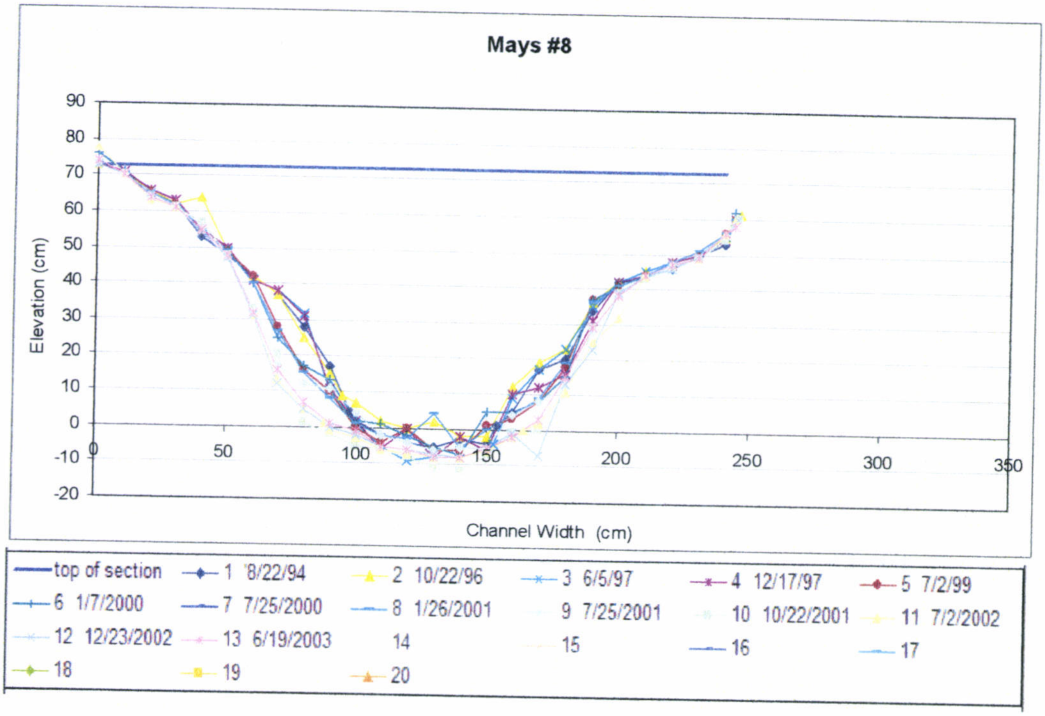

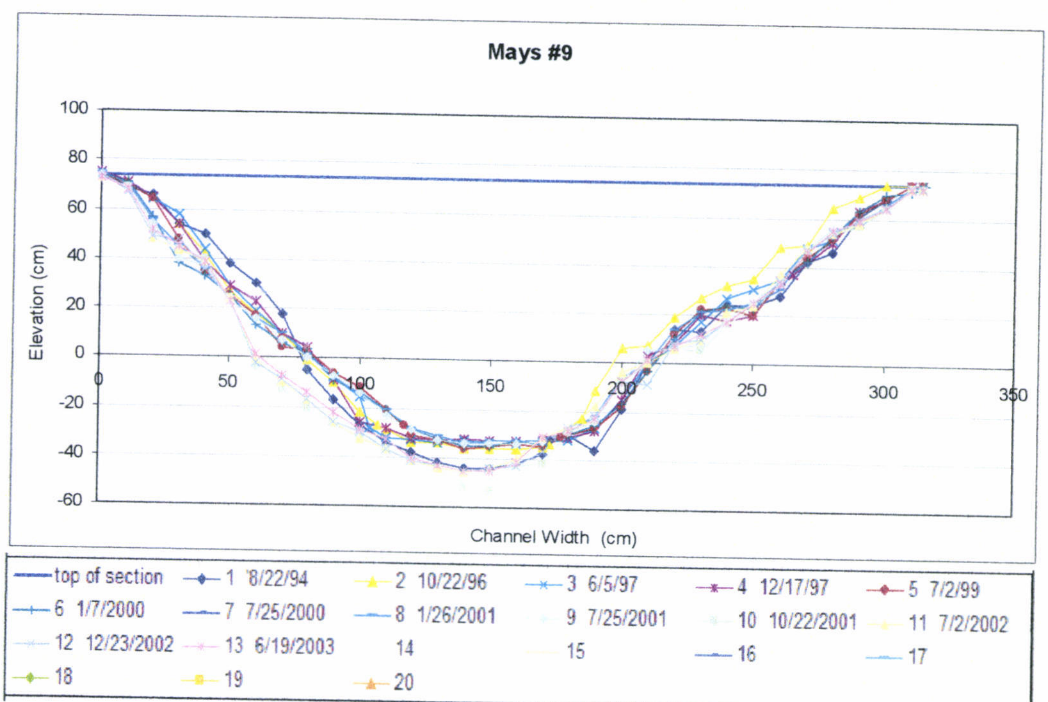

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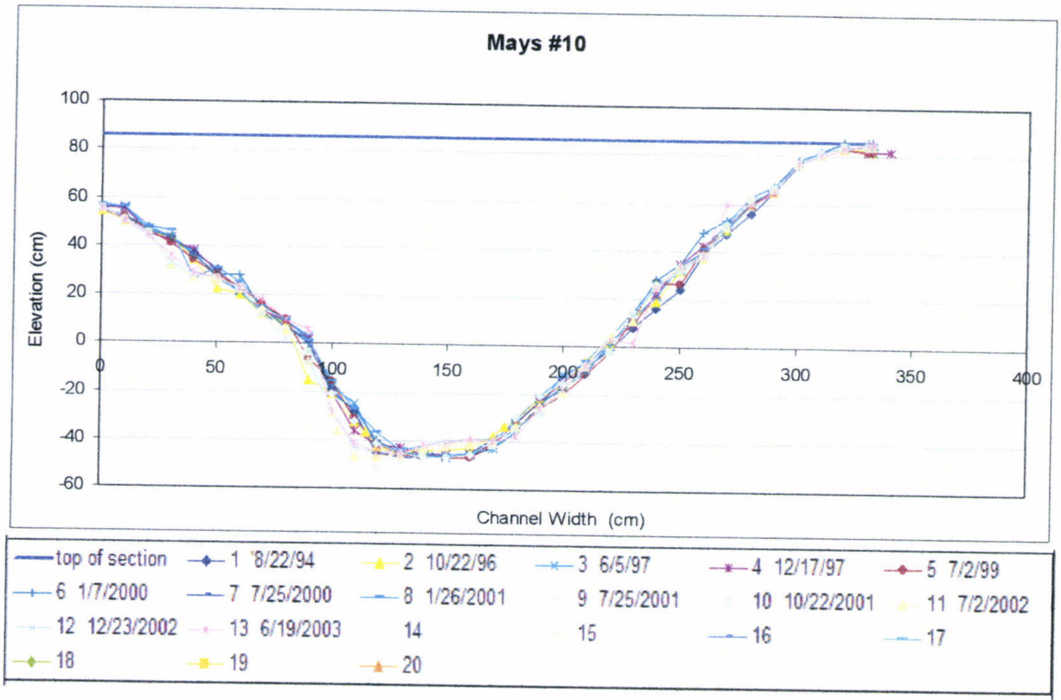

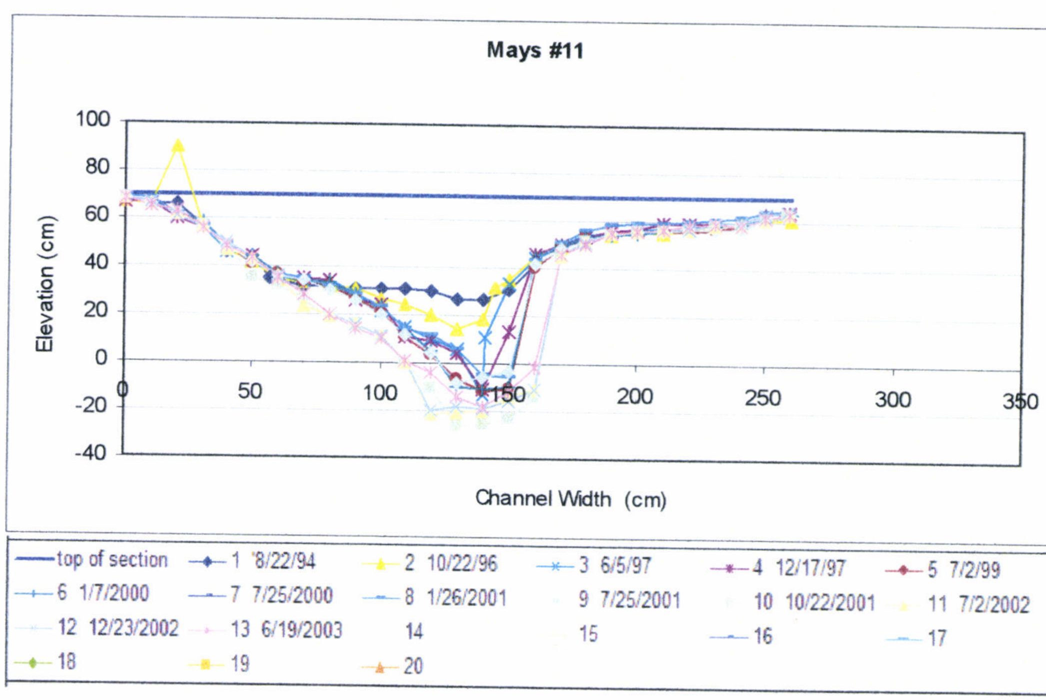

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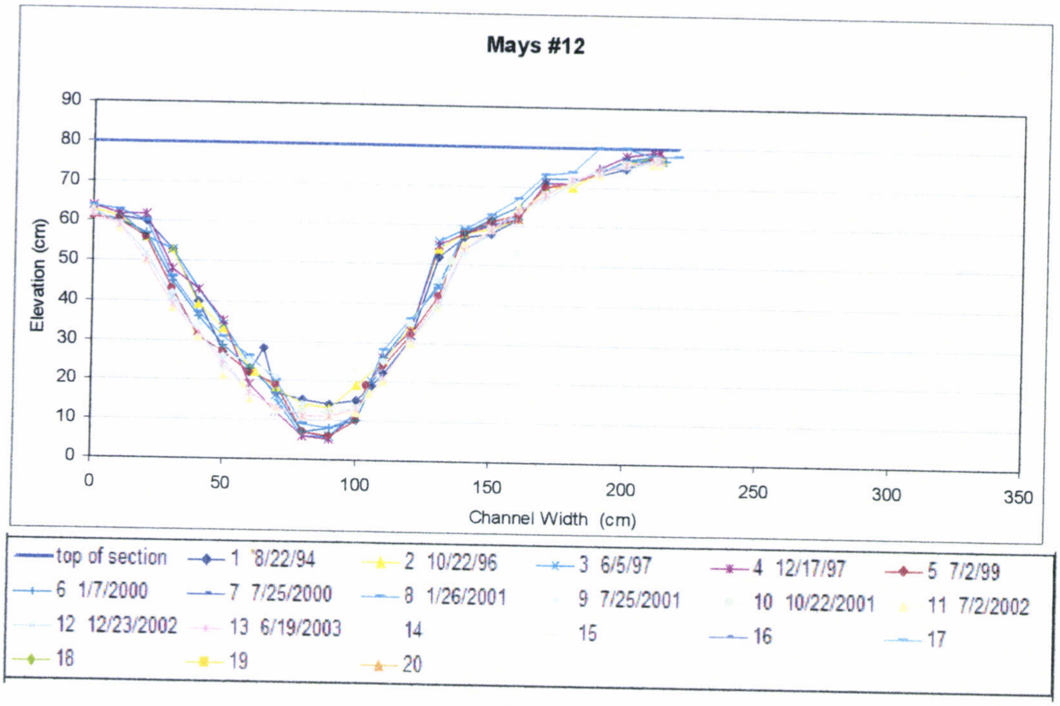

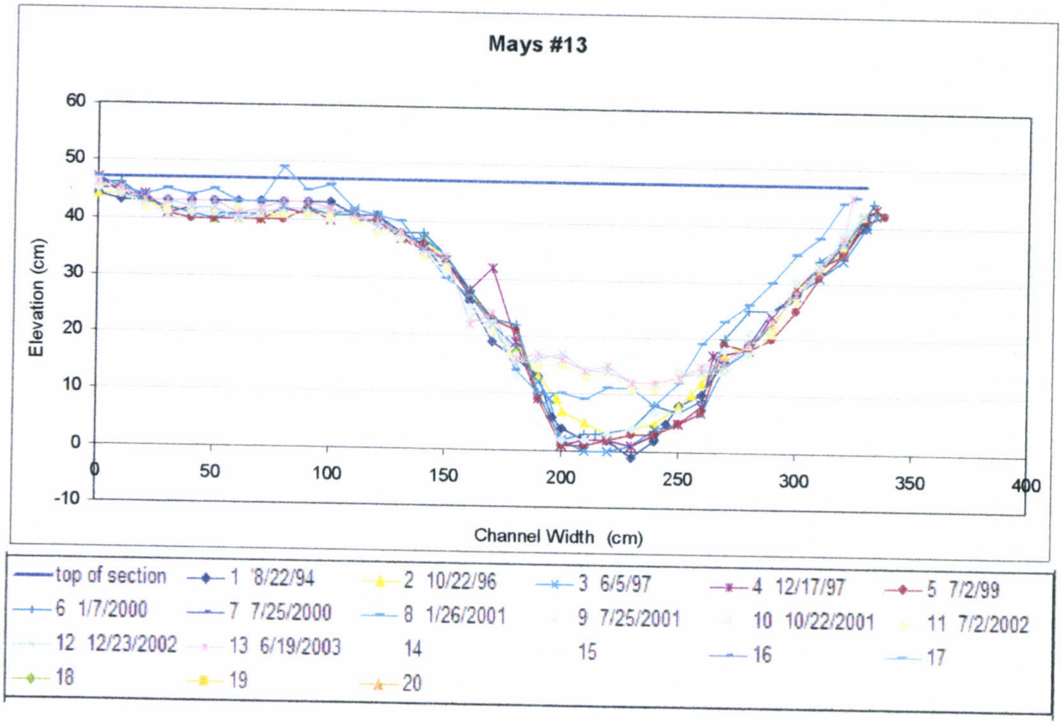

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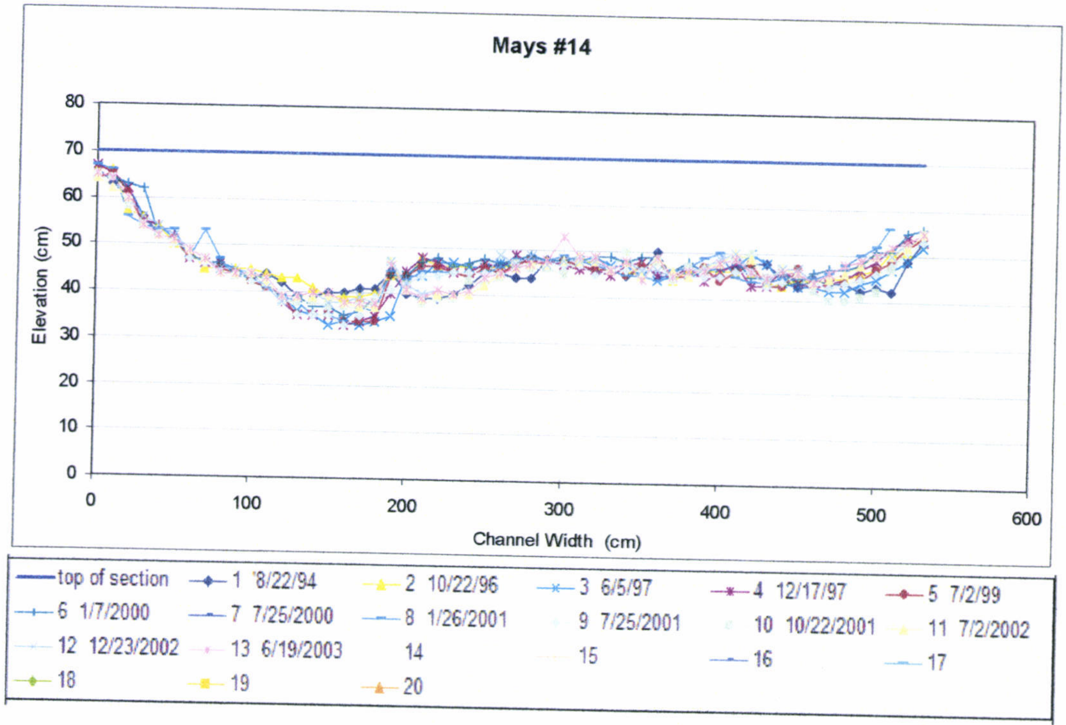

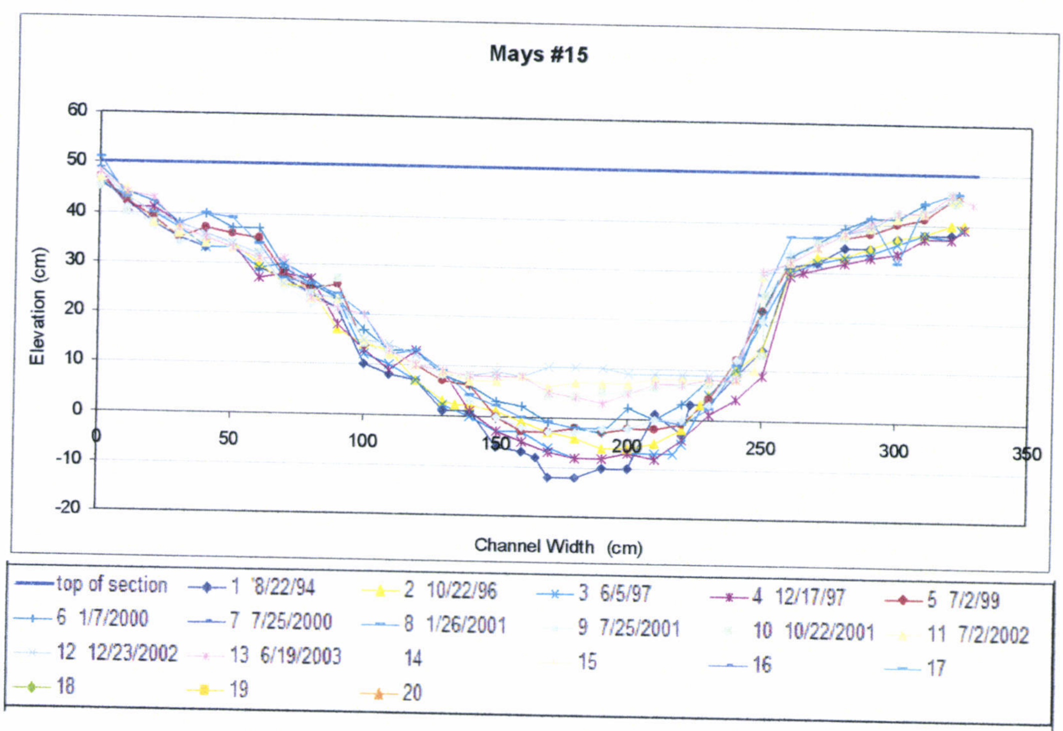

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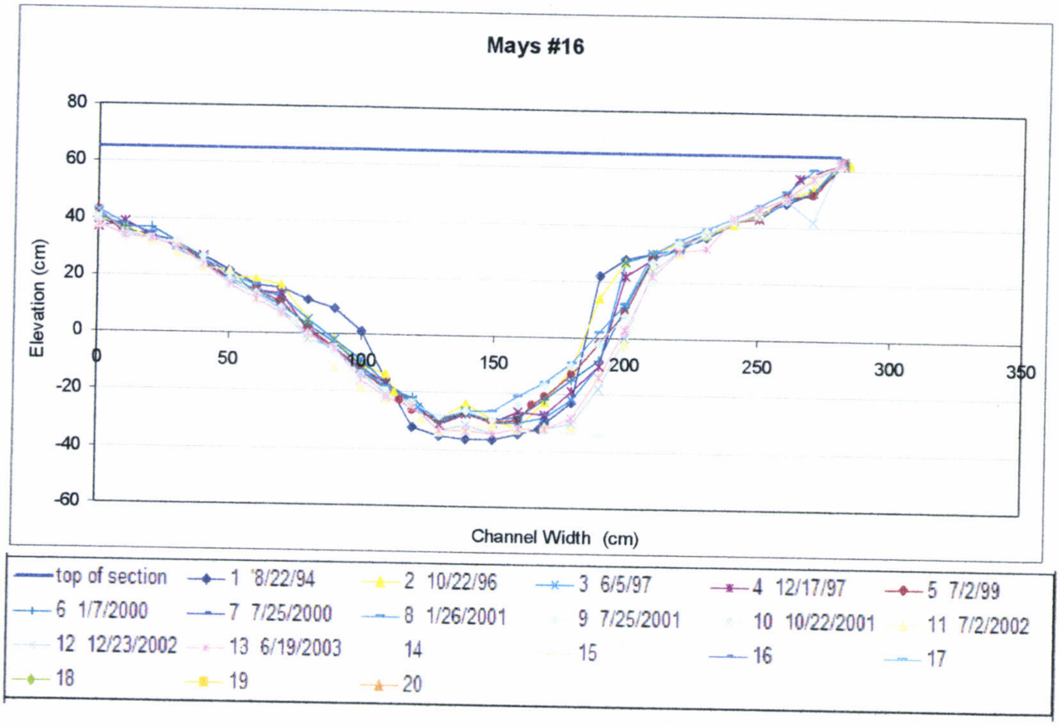

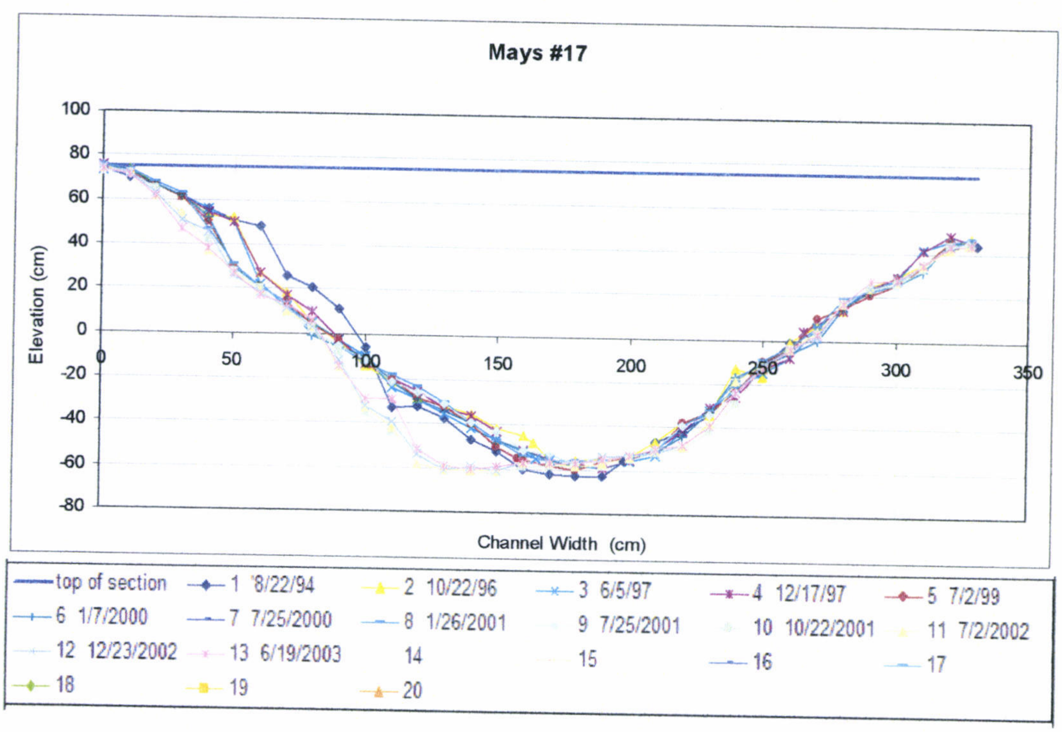

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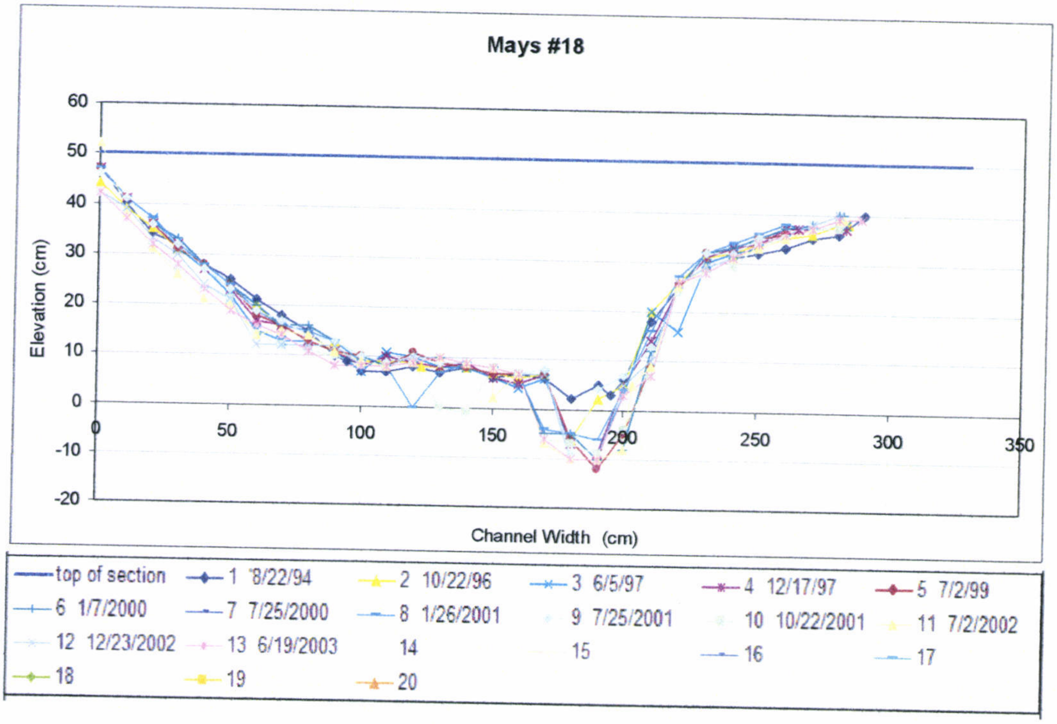

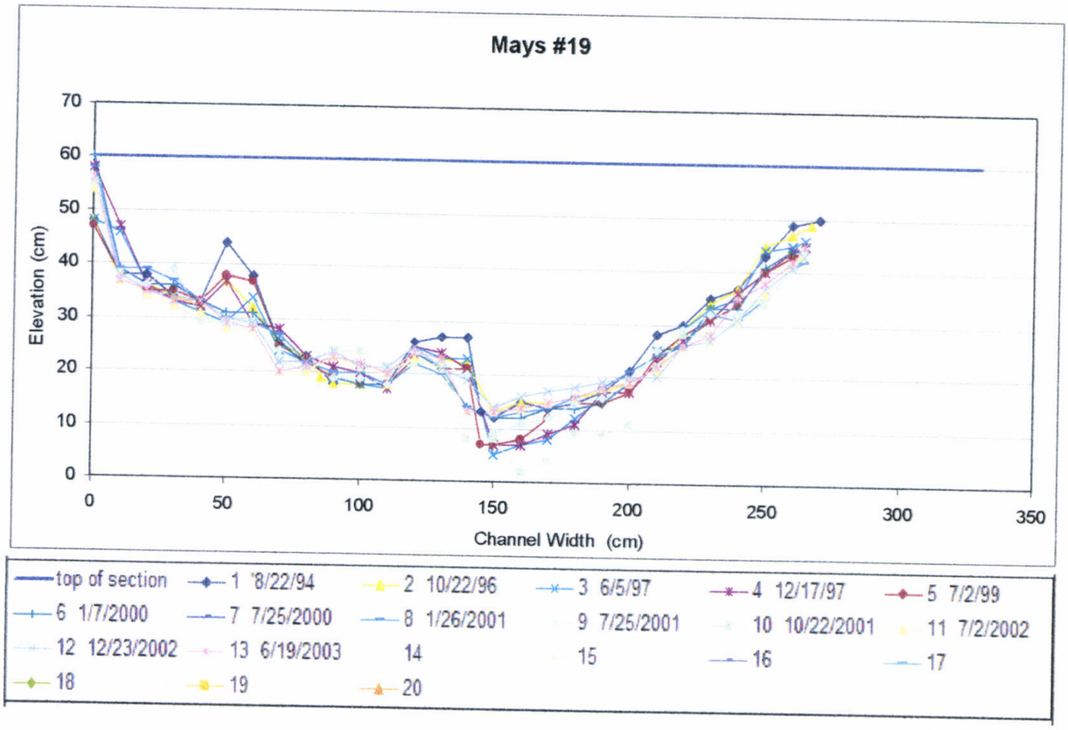

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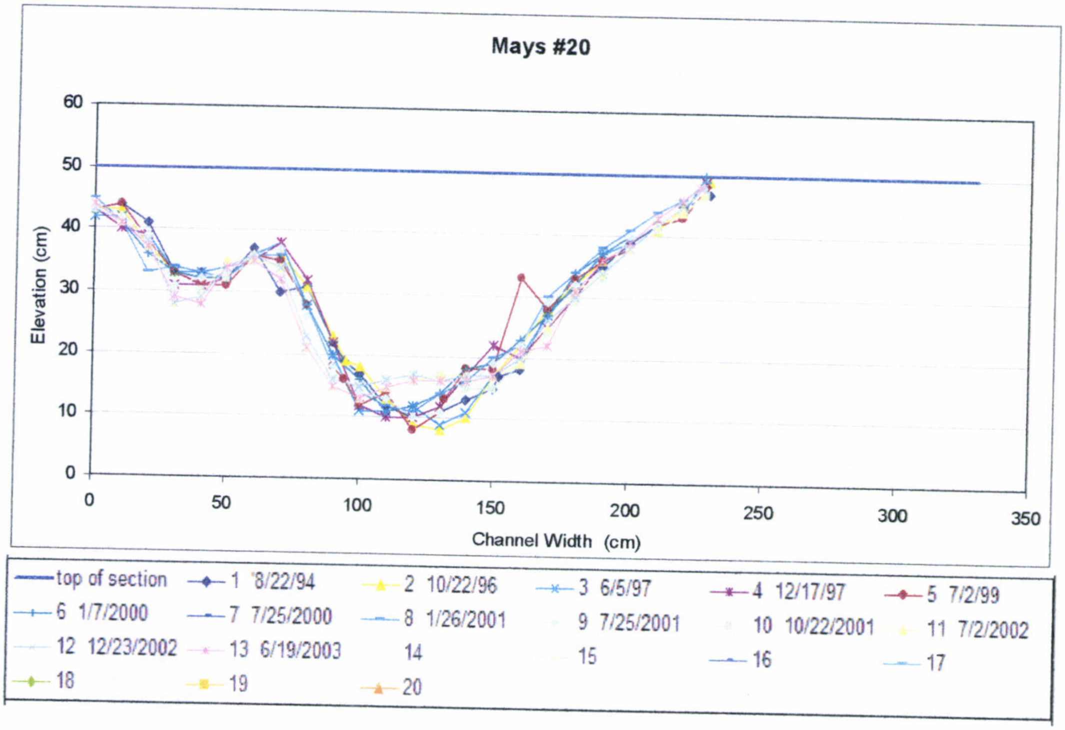

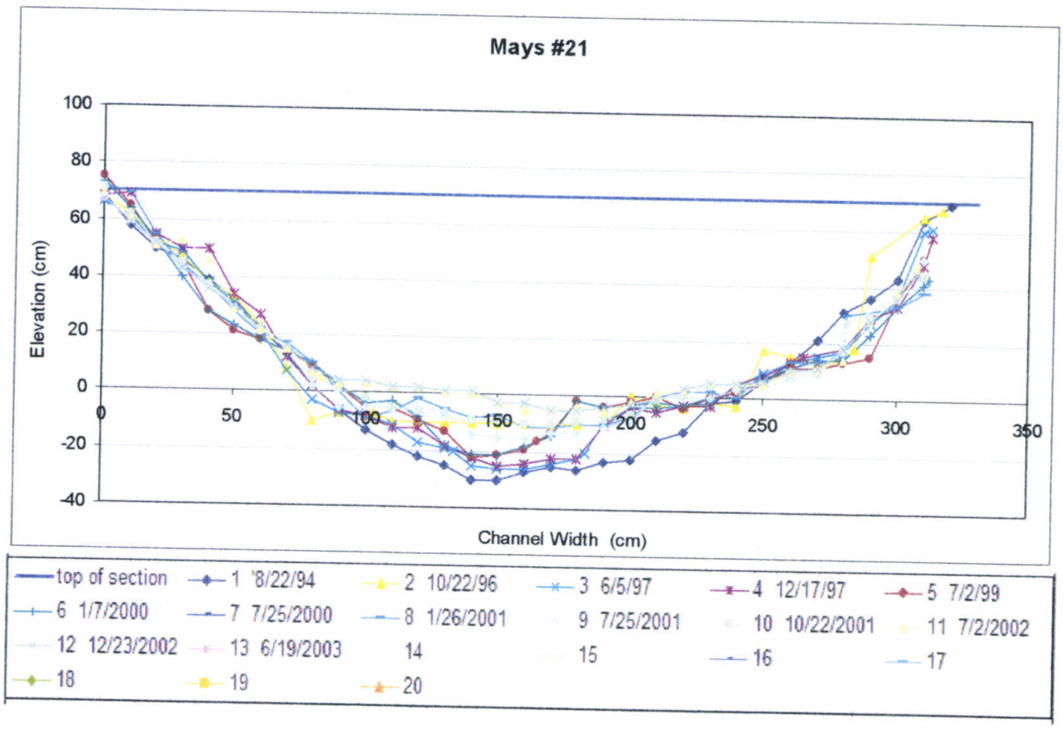

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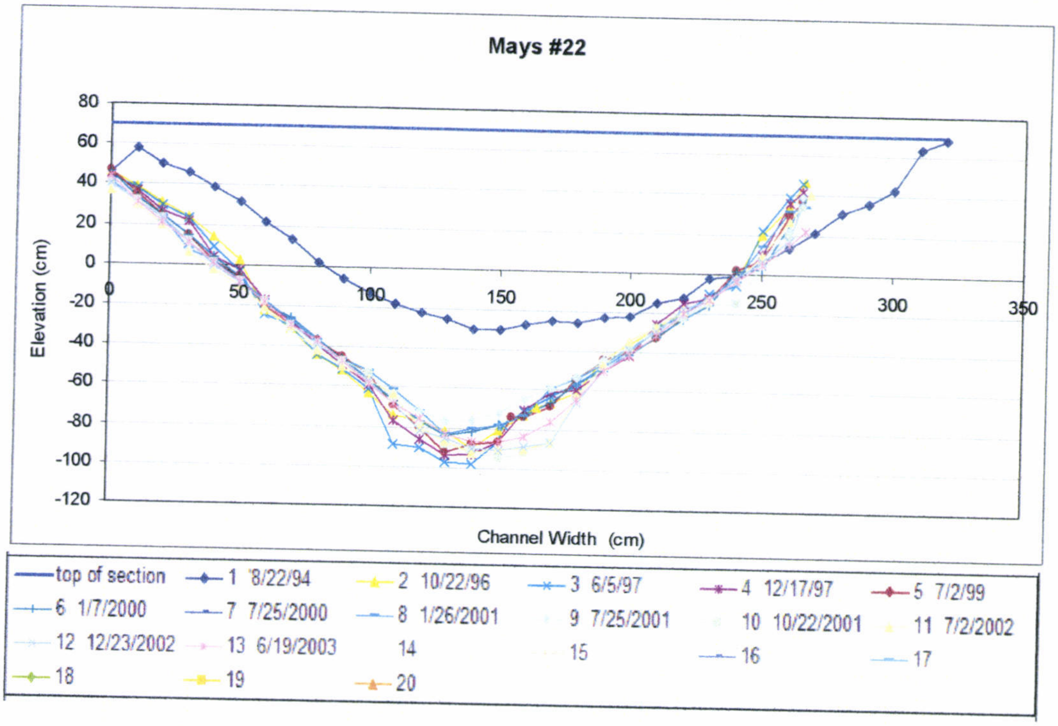
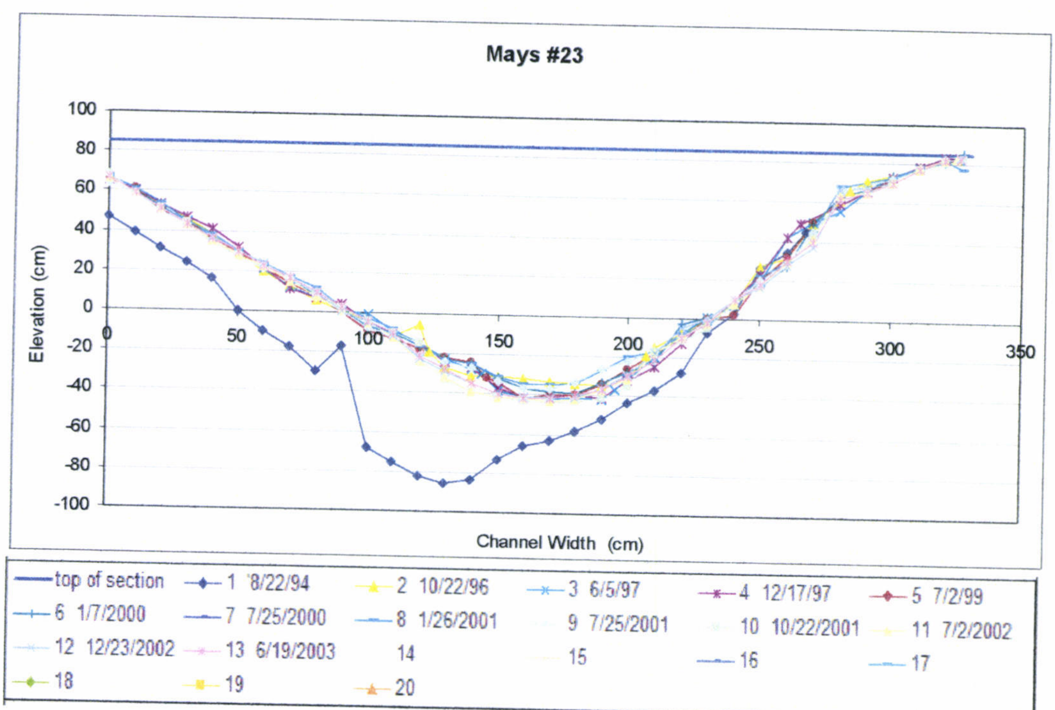
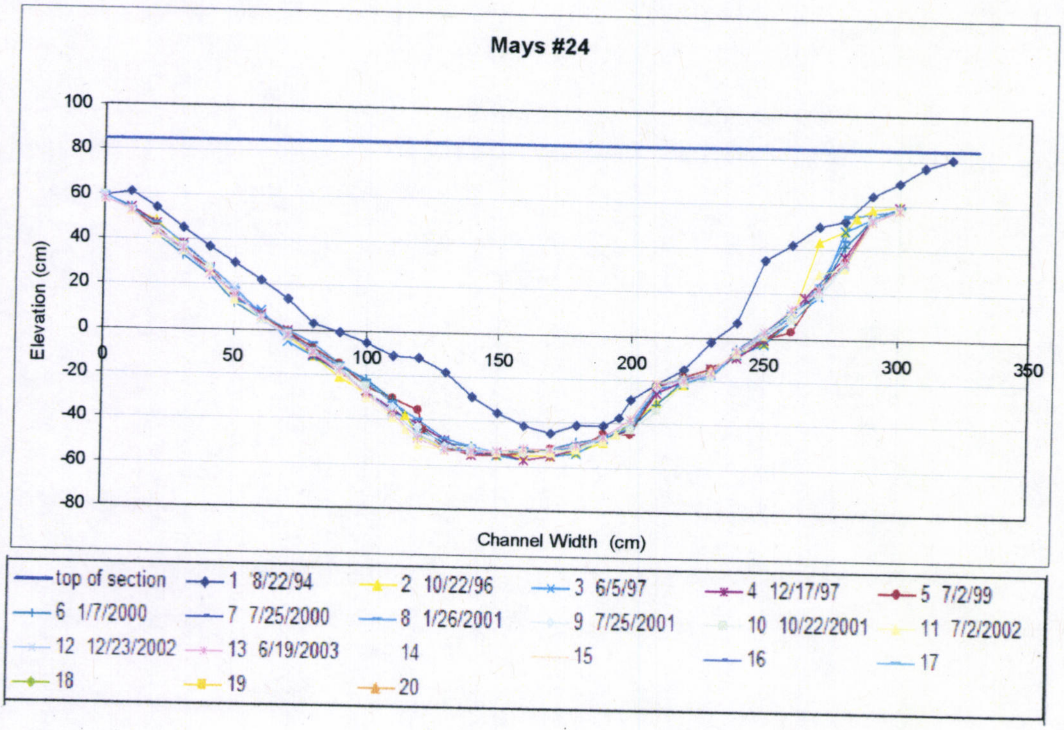
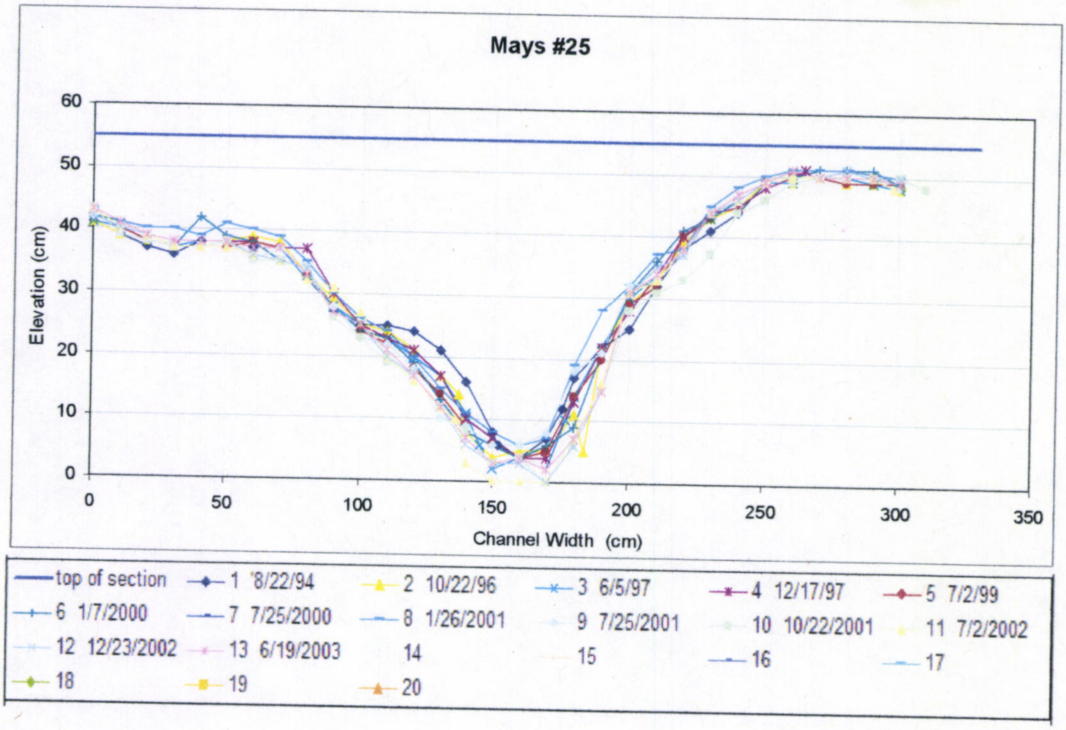




Appendix J. Continued.





Appendix J. Continued.

Appendix K1. Compiled cross-section area data.

Jensen from	cross-section # To	1	2	3	4	5	6
8/22/1994	10/22/1996	66	92	749	1375	-72	252
10/22/1996	6/5/1997	-233	-8	-916	-160	-2406	-9735
6/5/1997	12/17/1997	307	-56	270	313	105	115
12/17/1997	7/2/1999	-598	-202	-610	-703	-616	-600
7/2/1999	1/7/2000	522	255	598	370	304	619
	Sum	65	82	91	1195	-2684	-9350
1/26/2001	7/25/2001	-464	-129	-508	-437	103	-539
7/25/2001	10/22/2001	-151	-19	-654	711	-430	-207
10/22/2001	7/2/2002	212	-161	473	325	205	68
7/2/2002	12/23/2002	120	512	40	167	-133	-355
12/23/2002	6/19/2003		-312	-124	-55	82	-340
	Sum	-283	-109	-773	710	-174	-1371

Mays from	cross-section # To	1	2	3	4	5	6
8/22/1994	10/22/1996	316	3866	98	1092	-221	228
10/22/1996	6/5/1997	-11417	-13049	-8809	-10597	-7168	-10109
6/5/1997	12/17/1997	-144	-103	449	273	168	-67
12/17/1997	7/2/1999	-196	-142	-390	-139	-736	13
7/2/1999	1/7/2000	245	83	150	-269	541	238
	Sum	-11195	-9345	-8503	-9640	-7415	-9697
1/26/2001	7/25/2001	-980	-697	-962	-962	-318	-329
7/25/2001	10/22/2001	-470	-208	877	-16849	-887	-172
10/22/2001	7/2/2002	-161	-246	-88	102	631	-50
7/2/2002	12/23/2002	-262	228	156	187	-193	315
12/23/2002	6/19/2003	505	-187	17	100	280	-162
	Sum	-2160	-1800	-1546	-3337	-1392	-1799

Appendix K1. Compiled cross-section area data continued.

Jensen from	Cross-section # To	7	8	9	10	11	14
8/22/1994	10/22/1996	2192	-927	1678	505	-422	201
10/22/1996	6/5/1997	-8006	-6972	-5339	-7958	-7382	-6524
6/5/1997	12/17/1997	235	128	152	-4861	360	160
12/17/1997	7/2/1999	346	0	-315	4195	-552	-59
7/2/1999	1/7/2000	96	-10000	177	173	628	163
	Sum	-5137	-17771	-3647	-7947	-7368	-6060
1/26/2001	7/25/2001	-141	-144	-227	-536	-386	-240
7/25/2001	10/22/2001	-153	-317	1298	274	300	-215
10/22/2001	7/2/2002	234	67	289	-199	15	155
7/2/2002	12/23/2002	2383	-166	-5	15	85	-75
12/23/2002	6/19/2003	-2449	65	15	33	15	171
	Sum	-126	-495	1370	-413	29	-204

Mays from	cross-section # To	7	8	9	10	11	12
8/22/1994	10/22/1996	2758	398	1717	-25	-950	99
10/22/1996	6/5/1997	-9237	-7096	-9082	-4282	-8395	-4366
6/5/1997	12/17/1997	180	9	-215	-194	-223	-57
12/17/1997	7/2/1999	-233	-296	-75	-181	-699	-426
7/2/1999	1/7/2000	86	55	-186	528	163	211
	Sum	-6446	-6930	-7841	-4153	-10105	-4539
1/26/2001	7/25/2001	-336	-595	-379	-786	-663	-362
7/25/2001	10/22/2001	-195	-653	-2065	-556	-1892	-503
10/22/2001	7/2/2002	10	58	632	252	192	24
7/2/2002	12/23/2002	41	-33	-225	97	220	99
12/23/2002	6/19/2003	30	293	336	213	210	18
	Sum	-1213	-1344	-1580	-826	-2013	-891

Appendix K1. Compiled cross-section area data continued.

Jensen from	cross-section # to	15	16	17	18	19	20
8/22/1994	10/22/1996	-34	-684	-142	-231	617	-170
10/22/1996	6/5/1997	-5460	-4624	-4531	-6180	-4704	-8795
6/5/1997	12/17/1997	232	259	-9	294	-121	9330
12/17/1997	7/2/1999	-426	-563	352	-179	314	-9613
7/2/1999	1/7/2000	405	242	-87	120		289
	sum	-5283	-5370	-4416	-6176	-3895	-8960
1/26/2001	7/25/2001	-334	-270	-184	-341	-203	-89
7/25/2001	10/22/2001	-306	-158	182	-121	3399	-271
10/22/2001	7/2/2002	240	7	-204	235	2491	-66
7/2/2002	12/23/2002	-131	114	255	-112	-859	165
12/23/2002	6/19/2003	59	104	7	112	-245	10
	sum	-473	-204	56	-227	4584	-250

Mays from	cross-section # to	13	14	15	16	17	18
8/22/1994	10/22/1996	32	570	440	204	303	94
10/22/1996	6/5/1997	-17955	-16520	-16398	-10444	-8778	-14496
6/5/1997	12/17/1997	161	245	-268	48	453	179
12/17/1997	7/2/1999	-468	-200	1213	-160	-679	32
7/2/1999	1/7/2000	830	885	528	193	-48	-8
	sum	-17401	-15020	-14486	-10160	-8749	-14200
1/26/2001	7/25/2001	-1338	-1677	-443	-317	-447	195
7/25/2001	10/22/2001	506	5	686	-1273	-1845	-1043
10/22/2001	7/2/2002	-22	430	86	173	119	148
7/2/2002	12/23/2002	163	255	379	20	154	438
12/23/2002	6/19/2003	436	-59	-500	53	78	-834
	sum	-3187	-2826	-2615	-1970	-1767	-2682

Appendix K1. Compiled cross-section area data continued.

Jensen from	cross-section # to	23	24	25	average
8/22/1994	10/22/1996	26	445	-170	254
10/22/1996	6/5/1997	-7522	79	-8819	-5057
6/5/1997	12/17/1997	78	99	275	365
12/17/1997	7/2/1999	-282	238	-360	-487
7/2/1999	1/7/2000	148	257	205	-226
	sum	-7553	1117	-8870	-5140
1/26/2001	7/25/2001	-205	-432	-225	-282
7/25/2001	10/22/2001	-97	340	-133	156
10/22/2001	7/2/2002	10	105	263	227
7/2/2002	12/23/2002	83	250	88	116
12/23/2002	6/19/2003	-46	-130	107	-146
	sum	-255	133	100	77

Mays from	cross-section # to	19	20	21	22	23	24
8/22/1994	10/22/1996	-304	16	1876	-6227	6741	-4480
		-	-	-			
10/22/1996	6/5/1997	10861	11423	10745	-8532	-5368	-4704
6/5/1997	12/17/1997	90	45	486	184	198	120
12/17/1997	7/2/1999	-84	64	224	5	-183	92
7/2/1999	1/7/2000	77	32	-101	19	190	-12
		-	-				
	sum	11082	11266	-8261	-14551	1578	-8984
1/26/2001	7/25/2001	-121	-98	-519	-156	-539	-599
7/25/2001	10/22/2001	-610	-248	405	-1240	-806	-298
10/22/2001	7/2/2002	538	90	1074	-50	71	228
7/2/2002	12/23/2002	256	87	-110	172	293	173
12/23/2002	6/19/2003	-129	-34	0	136	-73	-15
	sum	-2021	-2067	-1425	-2749	191	-1680

Appendix K1. Compiled cross-section area data continued.

Jensen from	cross-section # to
8/22/1994	10/22/1996
10/22/1996	6/5/1997
6/5/1997	12/17/1997
12/17/1997	7/2/1999
7/2/1999	1/7/2000
	sum
1/26/2001	7/25/2001
7/25/2001	10/22/2001
10/22/2001	7/2/2002
7/2/2002	12/23/2002
12/23/2002	6/19/2003
	sum

Mays from	cross-section # to	25	Average
8/22/1994	10/22/1996	-171	339
10/22/1996	6/5/1997	-13453	-10131
6/5/1997	12/17/1997	157	87
12/17/1997	7/2/1999	-223	-155
7/2/1999	1/7/2000	200	185
	sum	-13489	-9675
1/26/2001	7/25/2001	-520	-558
7/25/2001	10/22/2001	-1176	-1220
10/22/2001	7/2/2002	839	203
7/2/2002	12/23/2002	-14	116
12/23/2002	6/19/2003	90	32
	sum	-2524	-1889

Appendix K2. Compiled cross-section deposition data.

Jensen from	cross-section # to	1	2	3	4	5	6
8/22/1994	10/22/1996	832	464	1085	1750	831	578
10/22/1996	6/5/1997	670	385	192	807	413	139
6/5/1997	12/17/1997	425	294	1347	819	965	1408
12/17/1997	7/2/1999	467	337	1049	567	856	760
7/2/1999	1/7/2000	851	544	1675	809	1160	1234
	sum	3244	2023	5347	4752	4225	4119
1/26/2001	7/25/2001	5	5	142	48	240	17
7/25/2001	10/22/2001	125	186	611	1150	10	15
10/22/2001	7/2/2002	247	95	1149	669	698	138
7/2/2002	12/23/2002	125	552	301	230	490	60
12/23/2002	6/19/2003		100	95	20	120	303
	sum	502	938	2298	2117	1557	533

Mays from	cross-section # to	1	2	3	4	5	6
8/22/1994	10/22/1996	2165	5514	748	2374	2266	2180
10/22/1996	6/5/1997	0	438	0	77	800	271
6/5/1997	12/17/1997	1075	1340	1303	743	345	363
12/17/1997	7/2/1999	1205	1360	718	2230	1655	1826
7/2/1999	1/7/2000	1730	1393	735	1696	1985	1701
	sum	6175	10044	3503	7119	7050	6339
1/26/2001	7/25/2001	570	745	315	315	105	41
7/25/2001	10/22/2001	325	150	1027	40	25	213
10/22/2001	7/2/2002	2175	129	653	1522	1708	305
7/2/2002	12/23/2002	1938	268	809	347	1420	365
12/23/2002	6/19/2003	605	115	82	255	295	210
	sum	5613	1407	2885	2479	3553	1134

Appendix K2. Compiled cross-section deposition data continued.

Jensen from	cross-section # To	7	8	9	10	11	14
8/22/1994	10/22/1996	2906	586	1879	1845	510	654
10/22/1996	6/5/1997	398	203	26	111	336	79
6/5/1997	12/17/1997	1679	954	567	1071	1127	1392
12/17/1997	7/2/1999	1468	0	323	5065	95	798
7/2/1999	1/7/2000	909	0	435	250	628	850
	sum	7360	1742	3229	8342	2696	3772
1/26/2001	7/25/2001	75	10	10	35	64	75
7/25/2001	10/22/2001	67	55	1355	570	990	70
10/22/2001	7/2/2002	294	192	314	156	795	165
7/2/2002	12/23/2002	2545	50	75	95	105	30
12/23/2002	6/19/2003	87	85	100	118	45	225
	sum	3067	392	1854	974	1999	565

Mays from	cross-section # To	7	8	9	10	11	12
8/22/1994	10/22/1996	3276	1160	3335	2378	820	815
10/22/1996	6/5/1997	224	435	202	491	529	668
6/5/1997	12/17/1997	1546	886	1535	170	729	1446
12/17/1997	7/2/1999	728	114	2880	299	25	802
7/2/1999	1/7/2000	819	170	2577	573	220	928
	sum	6591	2765	10528	3911	2323	4659
1/26/2001	7/25/2001	0	55	90	10	20	248
7/25/2001	10/22/2001	175	50	50	115	59	438
10/22/2001	7/2/2002	80	1991	687	1577	335	1461
7/2/2002	12/23/2002	115	1848	125	1549	245	1515
12/23/2002	6/19/2003	95	328	395	443	360	73
	sum	465	4272	1347	3694	1019	3735

Appendix K2. Compiled cross-section deposition data continued.

Jensen from	cross-section # To	15	16	17	18	20	23
8/22/1994	10/22/1996	735	874	1179	695	409	464
10/22/1996	6/5/1997	107	356	479	56	98	20
6/5/1997	12/17/1997	809	956	955	1099	9340	723
12/17/1997	7/2/1999	1392	803	1642	1581	1012	1289
7/2/1999	1/7/2000	1722	980	1836	1666	1161	1457
	sum	4765	3969	6090	5096	12019	3953
1/26/2001	7/25/2001	0	35	230	15	221	65
7/25/2001	10/22/2001	628	585	802	40	525	58
10/22/2001	7/2/2002	857	837	683	854	624	35
7/2/2002	12/23/2002	15	933	255	837	170	125
12/23/2002	6/19/2003	129	134	90	949	55	40
	sum	1628	2523	2060	2695	1595	323

Mays from	cross-section # to	13	14	15	16	17	18
8/22/1994	10/22/1996	581	760	1189	1485	2252	1034
10/22/1996	6/5/1997	18	0	267	361	0	48
6/5/1997	12/17/1997	1629	500	1216	1558	2383	535
12/17/1997	7/2/1999	488	165	1595	2485	1864	532
7/2/1999	1/7/2000	1302	895	558	2505	1541	185
	sum	4017	2320	4824	8394	8040	2334
1/26/2001	7/25/2001	0	115	157	128	174	340
7/25/2001	10/22/2001	730	485	1436	1233	105	62
10/22/2001	7/2/2002	893	510	463	1609	329	1990
7/2/2002	12/23/2002	1035	340	1010	1408	290	2092
12/23/2002	6/19/2003	446	209	130	275	285	45
	sum	3103	1659	3196	4652	1183	4529

Appendix K2. Compiled cross-section deposition data continued.

Jensen from	cross-section # to	average
8/22/1994	10/22/1996	952
10/22/1996	6/5/1997	260
6/5/1997	12/17/1997	1319
12/17/1997	7/2/1999	997
7/2/1999	1/7/2000	933
	sum	
1/26/2001	7/25/2001	66
7/25/2001	10/22/2001	420
10/22/2001	7/2/2002	464
7/2/2002	12/23/2002	371
12/23/2002	6/19/2003	150
	sum	

Mays from	cross-section # to	21	22	23	24	25	average
8/22/1994	10/22/1996	2747	1753	9423	915	638	2027
10/22/1996	6/5/1997	879	1105	1571	460	17	359
6/5/1997	12/17/1997	3023	1953	2760	638	1978	1202
12/17/1997	7/2/1999	2253	1983	1620	1940	260	1269
7/2/1999	1/7/2000	1099	1737	1580	1700	285	1228
	sum	10000	8530	16953	5652	3177	
1/26/2001	7/25/2001	197	335	84	427	487	208
7/25/2001	10/22/2001	1152	265	459	118	10	360
10/22/2001	7/2/2002	1881	415	236	2748	1159	1027
7/2/2002	12/23/2002	1076	437	380	2720	998	910
12/23/2002	6/19/2003	0	390	135	80	115	223
	sum	4306	1842	1294	6092	2769	

Appendix K3. Compiled cross-section scour data.

Jensen from	cross-section # to	2	3	4	5	6
8/22/1994	**10/22/1996**	372	337	375	903	326
10/22/1996	**6/5/1997**	393	1108	967	2819	9874
6/5/1997	**12/17/1997**	349	1077	507	860	1294
12/17/1997	**7/2/1999**	539	1658	1269	1472	1360
7/2/1999	**1/7/2000**	288	1077	439	856	615
	sum	**1941**	**5256**	**3557**	**6909**	**13468**
1/26/2001	**7/25/2001**	134	650	485	138	555
7/25/2001	**10/22/2001**	205	1265	439	440	222
10/22/2001	**7/2/2002**	256	676	345	493	70
7/2/2002	**12/23/2002**	40	261	63	623	415
12/23/2002	**6/19/2003**	412	219	75	38	643
	sum	**1047**	**3071**	**1407**	**1731**	**1904**
		2988	8327	4963	8640	15372

Mays from	cross-section # to	1	2	3	4	5
8/22/1994	**10/22/1996**	1849	1648	650	1282	2486
10/22/1996	**6/5/1997**	11417	13487	8809	10603	7968
6/5/1997	**12/17/1997**	1218	1443	854	470	177
12/17/1997	**7/2/1999**	1401	1502	1108	2369	2390
7/2/1999	**1/7/2000**	1485	1310	585	1965	1445
	sum	**17370**	**19389**	**12005**	**16689**	**14465**
1/26/2001	**7/25/2001**	1550	1442	1277	1277	423
7/25/2001	**10/22/2001**	795	358	150	16889	912
10/22/2001	**7/2/2002**	2336	375	740	1420	1077
7/2/2002	**12/23/2002**	2200	40	653	160	1613
12/23/2002	**6/19/2003**	100	302	65	156	15
	sum	**6981**	**2517**	**2885**	**19902**	**4039**

Appendix K3. Compiled cross-section scour data continued.

Jensen from	cross-section # to	7	8	9	10	11
8/22/1994	**10/22/1996**	714	1513	201	1340	932
10/22/1996	**6/5/1997**	8404	7175	5365	8069	7718
6/5/1997	**12/17/1997**	1444	826	415	5932	767
12/17/1997	**7/2/1999**	1123	0	638	871	647
7/2/1999	**1/7/2000**	813	10000	258	78	0
	sum	**12497**	**19513**	**6876**	**16289**	**10064**
1/26/2001	**7/25/2001**	215	154	237	570	450
7/25/2001	**10/22/2001**	220	372	57	297	690
10/22/2001	**7/2/2002**	60	125	25	355	780
7/2/2002	**12/23/2002**	163	216	80	80	20
12/23/2002	**6/19/2003**	2535	20	85	85	30
	sum	**3193**	**887**	**484**	**1387**	**1970**
		15690	20400	7360	17676	12034

Mays from	cross-section # to	6	7	8	9	10
8/22/1994	**10/22/1996**	1952	518	762	1618	2402
10/22/1996	**6/5/1997**	10380	9460	7531	9284	4773
6/5/1997	**12/17/1997**	430	1366	878	1750	364
12/17/1997	**7/2/1999**	1813	961	410	2955	480
7/2/1999	**1/7/2000**	1463	733	115	2763	45
	sum	**16036**	**13037**	**9695**	**18369**	**8064**
1/26/2001	**7/25/2001**	370	336	650	469	796
7/25/2001	**10/22/2001**	385	370	703	2115	671
10/22/2001	**7/2/2002**	355	70	1933	55	1325
7/2/2002	**12/23/2002**	50	75	1881	350	1452
12/23/2002	**6/19/2003**	372	66	35	59	230
	sum	**1532**	**916**	**5201**	**3048**	**4474**

Appendix K3. Compiled cross-section scour data continued.

Jensen From	cross-section # to	16	17	18	19	20
8/22/1994	10/22/1996	1558	1320	926	718	579
10/22/1996	6/5/1997	4980	5010	6236	5113	8893
6/5/1997	12/17/1997	697	964	805	633	10
12/17/1997	7/2/1999	1366	1291	1759	657	10625
7/2/1999	1/7/2000	738	1922	1546		872
	sum	9339	10506	11271	7121	20979
1/26/2001	7/25/2001	305	414	356	300	310
7/25/2001	10/22/2001	743	620	160	627	795
10/22/2001	7/2/2002	830	887	620	644	690
7/2/2002	12/23/2002	819	0	949	2290	5
12/23/2002	6/19/2003	30	83	837	245	45
	sum	2727	2004	2922	4105	1845
		12066	12510	14193	11226	22823

Mays from	cross-section # to	13	14	15	16	17
8/22/1994	10/22/1996	549	190	749	1281	1949
10/22/1996	6/5/1997	17973	16520	16665	10805	8778
6/5/1997	12/17/1997	1468	255	1483	1511	1930
12/17/1997	7/2/1999	956	365	383	2645	2543
7/2/1999	1/7/2000	473	10	30	2313	1589
	sum	21418	17340	19310	18554	16789
1/26/2001	7/25/2001	1338	1792	600	445	620
7/25/2001	10/22/2001	224	480	750	2505	1950
10/22/2001	7/2/2002	915	80	377	1436	210
7/2/2002	12/23/2002	873	85	632	1389	136
12/23/2002	6/19/2003	10	268	630	223	207
	sum	3359	2705	2989	5997	3123

Appendix K3. Compiled cross-section scour data continued.

Jensen	cross-section #	23	24	25	
from	to				average
8/22/1994	10/22/1996	439	240	249	713
10/22/1996	6/5/1997	7542	145	8919	5545
6/5/1997	12/17/1997	645	89	0	956
12/17/1997	7/2/1999	1571	195	365	1504
7/2/1999	1/7/2000	1309	0	26	1202
	sum	**11505**	**669**	**9559**	
1/26/2001	7/25/2001	270	442	240	344
7/25/2001	10/22/2001	155	25	323	444
10/22/2001	7/2/2002	25	35	70	381
7/2/2002	12/23/2002	42	15	67	320
12/23/2002	6/19/2003	85	160	20	288
	sum	**577**	**677**	**720**	
		12082	1346	10278	

Mays	cross-section #	18	19	20	21	22
from	to					
8/22/1994	10/22/1996	940	773	389	871	7980
10/22/1996	6/5/1997	14544	10945	11453	11624	9637
6/5/1997	12/17/1997	357	125	150	2537	1769
12/17/1997	7/2/1999	500	1079	1631	2029	1978
7/2/1999	1/7/2000	193	1020	1655	1200	1718
	sum	**16534**	**13941**	**15278**	**18261**	**23081**
1/26/2001	7/25/2001	145	255	205	715	490
7/25/2001	10/22/2001	1105	735	413	748	1505
10/22/2001	7/2/2002	1842	120	85	808	465
7/2/2002	12/23/2002	1655	65	20	1186	265
12/23/2002	6/19/2003	879	220	150	0	254
	sum	**5626**	**1395**	**873**	**3456**	**2979**

Appendix K3. Compiled cross-section scour data continued.

Jensen	cross-section #
from	to
8/22/1994	10/22/1996
10/22/1996	6/5/1997
6/5/1997	12/17/1997
12/17/1997	7/2/1999
7/2/1999	1/7/2000
	sum
1/26/2001	7/25/2001
7/25/2001	10/22/2001
10/22/2001	7/2/2002
7/2/2002	12/23/2002
12/23/2002	6/19/2003
	sum

Mays	cross-section #	24	25	
from	to			average
8/22/1994	10/22/1996	5395	809	1688
10/22/1996	6/5/1997	5164	13469	10487
6/5/1997	12/17/1997	518	1821	1115
12/17/1997	7/2/1999	1848	483	1423
7/2/1999	1/7/2000	1712	85	1043
	sum	14636	16666	
1/26/2001	7/25/2001	1026	1006	766
7/25/2001	10/22/2001	415	1186	1581
10/22/2001	7/2/2002	2520	320	824
7/2/2002	12/23/2002	2548	1012	795
12/23/2002	6/19/2003	95	25	191
	sum	6603	3549	

Appendix L1. Cross-section area data statistical output.

Cross-section Area:

The regression equation is
y = - 91 + 1.85 x

Predictor	Coef	StDev	T	P
Constant	-90.5	203.5	-0.44	0.668
x	1.8525	0.1220	15.19	0.000

S = 611.2 R-Sq = 96.6% R-Sq(adj) = 96.2%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	86169656	86169656	230.67	0.000
Residual Error	8	2988451	373556		
Total	9	89158107			

Regression
Without outlier data

The regression equation is
y = - 75 + 0.492 x

Predictor	Coef	StDev	T	P
Constant	-75.3	175.7	-0.43	0.681
x	0.4916	0.7095	0.69	0.511

S = 527.0 R-Sq = 6.4% R-Sq(adj) = 0.0%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	133345	133345	0.48	0.511
Residual Error	7	1943751	277679		
Total	8	2077097			

One-way Analysis of Variance

Analysis of Variance

Source	DF	SS	MS	F	P
Factor	1	1438301	1438301	0.23	0.640
Error	18	114266981	6348166		
Total	19	115705282			

```
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level      N      Mean     StDev   ---+---------+---------+---------+---
Jensen    10      -523      1670         (-------------*-------------)
Mays      10     -1059      3147   (-------------*------------)
                                   ---+---------+---------+---------+---
Pooled StDev =    2520              -2400     -1200         0      1200
```

Appendix L1. Cross-section area data statistical output continued.

Current worksheet: Area summed over time.MTW

One-way Analysis of Variance

```
Analysis of Variance for Sums
Source     DF        SS         MS         F        P
Watershe    1 203782475  203782475     10.09    0.002
Error      98 1.980E+09   20204134
Total      99 2.184E+09
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean      StDev  -----+---------+---------+---------+-
Jensen     50     -2577       4183                        (--------*-------)
Mays       50     -5432       4786  (--------*-------)
                                    -----+---------+---------+---------+-
Pooled StDev =     4495               -6000     -4500     -3000     -1500
```

Appendix L2. Cross-section deposition data statistical output.

One-way Analysis of Variance

```
Analysis of Variance for Average
Source     DF        SS        MS        F        P
Watershe    1    331531    331531     1.32    0.265
Error      18   4509744    250541
Total      19   4841276
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ---------+---------+---------+---
----
Jensen     10     624.0     395.2   (------------*------------)
Mays       10     881.5     587.3          (------------*--------
-----)

                                   ---------+---------+---------+---
----
Pooled StDev =    500.5                   500       750      1000
```

Kruskal-Wallis Test

```
Kruskal-Wallis Test on Average

Watershe    N    Median    Ave Rank        Z
Jensen     10     592.5         9.1    -1.06
Mays       10     968.5        11.9     1.06
Overall    20                  10.5

H = 1.12  DF = 1  P = 0.290
```

Current worksheet: Area averaged over x-sections.MTW

Regression

```
The regression equation is
y = 102 + 1.25 x

Predictor       Coef      StDev         T        P
Constant       102.1      207.2      0.49    0.635
x             1.2490     0.2846      4.39    0.002

S = 337.5       R-Sq = 70.6%      R-Sq(adj) = 67.0%

Analysis of Variance
```

Appendix L2. Cross-section deposition data statistical output.

Source	DF	SS	MS	F	P
Regression	1	2192953	2192953	19.25	0.002
Residual Error	8	911125	113891		
Total	9	3104079			

Current worksheet: Area summed over time stacked.MTW

One-way Analysis of Variance

Analysis of Variance

Source	DF	SS	MS	F	P
Factor	1	42145452	42145452	5.60	0.020
Error	98	737141787	7521855		
Total	99	779287239			

```
                                        Individual 95% CIs For Mean
                                        Based on Pooled StDev
Level        N        Mean       StDev  ---+---------+---------+---------
+---
Jensen      50        2981        2369   (--------*---------)
Mays        50        4279        3071               (--------*------
---)
                                        ---+---------+---------+---------
+---
Pooled StDev =        2743              2400      3200      4000
4800
```

Appendix L3. Cross-section scour data statistical output.

Current worksheet: Scour summed over time.MTW

One-way Analysis of Variance

```
Analysis of Variance for Sum
Source      DF          SS          MS          F          P
Watershe     1   392812537   392812537      10.96      0.001
Error       98   3.513E+09    35849350
Total       99   3.906E+09
                                        Individual 95% CIs For Mean
                                        Based on Pooled StDev
Level        N        Mean       StDev  -+---------+---------+---------+-
----
Jensen      50        5558        5322  (--------*-------)
Mays        50        9522        6586                      (--------*---
----)

                                        -+---------+---------+---------+-
----
Pooled StDev =        5987            4000      6000      8000     10000
```

Current worksheet: Scour averaged over x-section.MTW

One-way Analysis of Variance

```
Analysis of Variance
Source      DF          SS          MS          F          P
Factor       1     3332321     3332321       0.58      0.458
Error       18   104298535     5794363
Total       19   107630855
                                        Individual 95% CIs For Mean
                                        Based on Pooled StDev
Level        N        Mean       StDev  ----+---------+---------+--------
-+--
Jensen      10        1147        1570  (-------------*------------)
Mays        10        1963        3021        (------------*------------
-)

                                        ----+---------+---------+--------
-+--
Pooled StDev =        2407                  0      1200      2400
3600
```

Appendix L3. Cross-section scour data statistical output continued.

Regression

The regression equation is
y = - 201 + 1.89 x

Predictor	Coef	StDev	T	P
Constant	-200.8	251.2	-0.80	0.447
x	1.8868	0.1336	14.12	0.000

S = 629.3 R-Sq = 96.1% R-Sq(adj) = 95.7%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	78952788	78952788	199.34	0.000
Residual Error	8	3168548	396069		
Total	9	82121336			

Appendix M. Flow data in cubic feet per second, by year and day. Data shows flow events that occurred in both Jensen and Mays.

Event #1

Year	Day	Mays	Jensen
1996	36	0.071217	0
1996	37	0.098125	0
1996	38	0.234516	0.019972
1996	39	0.292791	0
1996	40	0.195861	0.016847
1996	41	0.223104	0.014338
1996	42	0.241798	0.021377
1996	43	0.247707	0.041211
1996	44	0.25069	0.056728
1996	45	0.25069	0.058182
1996	46	0.252188	0.067257
1996	47	0.246223	0.072021
1996	48	0.249196	0.077771
1996	49	0.249196	0.073643
1996	50	0.247707	0.085468
1996	51	0.234516	0.077771
1996	52	0.230202	0.080299
1996	53	0.221699	0.032848
1996	54	0	0.063402
1996	55	0	0.029517
1996	56	0	0.023803
1996	57	0	0.025821

		Mays	Jensen
	226	0	0
1996	227	0.065702	0.191931
1996	228	0.050393	0.137826
1996	229	0.045045	0.122816
1996	230	0.042472	0.114622
1996	231	0.039966	0.11162
1996	232	0.036927	0.106704
1996	233	0.035154	0.102848
1996	234	0.032848	0.100946
1996	235	0.031164	0.097194
1996	236	0.028976	0.091693
1996	237	0.026337	0.08811
1996	238	0.024301	0.084596
1996	239	0.02282	0.085468
1996	240	0.022334	0.08811
1996	241	0.021377	0.087225
	242	0	0

Appendix M. Continued.

Events #2 and #3

Year	Day	Mays	Jensen	Day	Mays	Jensen
1997	11	0.134537	0	53		0
1997	12	0	0	54		0
1997	13	0	0.120742	55		0
1997	14		0.101895	56		0
1997	15		0	57	0.058915	0
1997	16		0	58	0.055291	0
1997	17	0.064931	0	59	0.051771	0
1997	18	0.119711	0	60	0.044396	0
1997	19	0.112617	0.041211	61	0.045045	0
1997	20	0.11162	0.047686	62		0.013538
1997	21	0.073643	0	63		0
1997	22		0	64	0	0
1997	23	0	0	65	0.036332	0
1997	24	0	0	66	0.063402	0
1997	25	0	0	67	0.029517	0
1997	26	0.047686	0	68	0.053166	0
1997	27	0.062644	0	69	0.032283	0
1997	28	0.105734	0	70	0.02738	0
1997	29	0.073643	0	71	0.026856	0
1997	30	0.300966	0.414328	72	0.027908	0
1997	31		0.240332	73	0.028976	0
1997	32	0.113617	0.189334	74	0.019972	0
1997	33		0.156032	75	0.017718	0
1997	34		0.151374	76	0.01728	0
1997	35		0.058182	77	0.015157	0
1997	36		0.015157	78	0.014338	0
1997	37	0	0	79	0.013936	0
1997	38		0	80	0.014338	0
1997	39		0	81	0.013538	0
1997	40		0	82	0.012371	0
1997	41	0.07283	0	83	0.012371	0
1997	42		0.151374	84	0.01199	0
1997	43	0.683088	0.13893	85	0.010878	0
1997	44		0	86	0.010878	0
1997	45		0	87	0.010516	0
1997	46		0.163151	88	0	0
1997	47		0.179126	89	0	0
1997	48		0.176619	90	0	0
1997	49		0.165559	91	0	0
1997	50		0.169206	92	0.016847	0
1997	51		0.16076			
1997	52		0			

Appendix M. Continued.

Event #4		Mays	Jensen			
1999	75	0	0.053166	119		0.064931
1999	76	0	0.118684	120		0.052467
1999	77	0	0.03935	121		0.050393
1999	78	0	0.329655	122		0.059652
1999	79	0	0.635213	123		0.055291
1999	80	0	0.372537	124		0.048356
1999	81	0	0.317674	125		0.041211
1999	82	0	0.357931	126		0.032848
1999	83	0	0.391236	127		0.02844
1999	84	0		128		0.024301
1999	85	0	0.485799	129		0.019057
1999	86	0	0.481548	130		0.014338
1999	87	0	0.471009	131		0.011615
1999	88	0	0.456469	132		0
1999	89	0	0.440154	133		0
1999	90	0	0.416285	134		0
1999	91	0	0.402693	135		0
1999	92	0	0.395035	136		0
1999	93	0	0.385575	137		0
1999	94	0	0.379958	138	0.085468	0
1999	95	0	0.368856	139	0.07861	0
1999	96	0	0.365195	140	0.072021	0
1999	97	0	0.363372	141	0.066478	0
1999	98	0	0.363372	142	0.06189	0
1999	99	0	0.35974	143	0.060394	0
1999	100	0	0.356128	144	0.057453	0
1999	101	0	0.347182	145	0.052467	0
1999	102	0.237415	0.343638	146	0.050393	0
1999	103	0.238871	0.343638	147	0.046357	0
1999	104	0.246223	0.343638	148	0.044396	0
1999	105	0.255199	0.341873	149	0.04375	0
1999	106	0.264343	0.334863	150	0.04375	0
1999	107	0.270533	0.326208	151	0.03935	0
1999	108	0.278376	0.32278	152	0.036927	0
1999	109	0.281546	0.32278	153	0.03813	0
1999	110	0.283138	0.327929	154	0.036332	0
1999	111	0.283138	0.331386	155	0.034571	0
1999	112	0.276798	0.329655	156	0.033993	0
1999	113	0.268978	0.317674	157	0.035154	0
1999	114	0.258228		158	0.035154	0
1999	115		0.233073	159	0.034571	0
1999	116		0.084596	160	0.034571	0
1999	117		0.082865	161	0.033993	0
1999	118		0.076937	162	0.032283	0

Appendix M. Continued.

Event #4 Continued.

Year	Day	Mays	Jensen
1999	163	0.031721	0
1999	164	0.031164	0
1999	165	0.03061	0
1999	166	0.02844	0
1999	167	0.013538	0
1999	168	0.012755	0
1999	169	0.011244	0
1999	170	0.011615	0
1999	171	0.011615	0
1999	172	0.011615	0
1999	173	0.01199	0
1999	174	0.012371	0
1999	175	0.012371	0
1999	176	0.012755	0
1999	177	0.013538	0
1999	178	0.013144	0

Appendix M. Continued.

Event #5

Year	Day	Mays	Jensen	Day	Mays	Jensen
2002	66		0.010878	108	0.05387	0
2002	67		0	109	0.052467	0
2002	68		0	110	0.052467	0
2002	69		0	111	0.051771	0
2002	70		0.031721	112	0.04971	0
2002	71		0.013144	113	0.048356	0
2002	72		0.012755	114	0.05108	0
2002	73		0.012371	115	0.049031	0
2002	74		0.01199	116	0.047686	0
2002	75		0.011244	117	0.040586	0
2002	76		0	118	0.039966	0
2002	77		0	119	0.03813	0
2002	78		0.013144	120	0.037526	0
2002	79		0.026337	121	0.036927	0
2002	80		0.015993	122	0.034571	0
2002	81		0.015157	123	0.033993	0
2002	82		0.014745	124	0.032283	0
2002	83		0.013936	125	0.027908	0
2002	84		0.013538	126	0.031164	0
2002	85		0.012371	127	0.02844	0
2002	86		0.010878	128	0.030061	0
2002	87		0	129	0.02844	0
2002	88		0	130	0.026337	0
2002	89		0	131	0.023803	0
2002	90		0	132	0.023309	0
2002	91		0	133	0.01816	0
2002	92		0	134	0.014338	0
2002	93		0			
2002	94		0			
2002	95		0			
2002	96		0			
2002	97		0			
2002	98		0			
2002	99		0			
2002	100		0			
2002	101		0			
2002	102		0			
2002	103		0			
2002	104		0			
2002	105		0			
2002	106		0			
2002	107		0			

Appendix M. Continued.

1996 Summer event

		Jensen			Mays		
		Average	Max	Min	Average	Max	Min
225		0	0			0	
226	2120	0.885278	6.928206	0	0.402693	0.964445	0
226	2130	5.097938	6.495901	3.581615	0.948923	1.34635	0.608373
226	2140	2.004731	3.509002	1.243172	0.363372	0.591627	0.233073
226	2150	0.885278	1.232395	0.662695	0.16677	0.22593	0.118684
226	2200	0.547467	0.66017	0.456469	0.08811	0.118684	0.068828
226	2210	0.408488	0.450313	0.391236	0.064931	0.068828	0.06189
226	2220	0.379958	0.391236	0.370694	0.06114	0.062644	0.060394
226	2230	0.363372	0.370694	0.357931	0.060394	0.060394	0.058915
226	2240	0.345408	0.356128	0.336608	0.058915	0.060394	0.058182
226	2250	0.605965	2.888311	0.348962	1.485958	4.912067	0.08115
226	2300	4.920064	5.697554	3.233457	4.529542	5.962791	2.772562
226	2310	3.986045	5.52467	2.693173	1.566944	2.744055	0.832694
226	2320	1.874598	2.681942	1.350122	0.513928	0.815567	0.370694
226	2330	1.037682	1.369072	0.864613	0.262807	0.385575	0.184194
226	2340	0.75991	0.897209	0.618059	0.149072	0.180386	0.131288
226	2350	0.531671	0.618059	0.477317	0.122816	0.134537	0.116644
227	0	0.460598	0.475209	0.448271	0.115631	0.122816	0.11162
227	10	0.412376	0.446234	0.385575	0.104768	0.112617	0.098125
227	20	0.387457	0.398854	0.376238	0.095343	0.098125	0.093509
227	30	0.387457	0.396942	0.368856	0.092599	0.094424	0.091693
227	40	0.354329	0.368856	0.345408	0.090791	0.091693	0.090791
227	50	0.340113	0.345408	0.334863	0.090791	0.090791	0.089
227	100	0.334863	0.334863	0.331386	0.089893	0.090791	0.08811

Appendix M. Continued.

2001 summer event

		Jensen			Mays		
		Average	Max	Min	Average	Max	Min
215	2400	0	0	0	0	0	0
216	1140	0	0	0	2.028501	8.151707	0
216	1150	0	0	0	12.41435	17.42139	8.012302
216	1200	0	0	0	16.00223	16.90156	14.44145
216	1210	0	0	0	11.69407	14.32069	7.916623
216	1220	0	0	0	4.575404	7.758667	3.109762
216	1230	0	0	0	2.761138	3.140422	2.473703
216	1240	0	0	0	2.285384	2.468355	2.120308
216	1250	0	0	0	1.97642	2.115418	1.851889
216	1300	0	0	0	1.771455	1.851889	1.705994
216	1310	0	0	0	1.654644	1.705994	1.61254
216	1320	0	0	0	1.571058	1.61254	1.534254
216	1330	0	0	0	1.505974	1.534254	1.477995
216	1340	0	0	0	1.470056	1.485958	1.450317
216	1350	0	0	0	1.438546	1.454252	1.42683
216	1400	0	0.013144	0	1.415169	1.430729	1.395856
216	1410	0.01199	0.012755	0.010878	1.34635	1.399707	1.261253
216	1420	0.012755	0.013144	0.012755	1.175816	1.261253	1.103842
216	1430	0.013144	0.013538	0.012755	1.080422	1.235982	1.018284
216	1440	0.012371	0.012755	0.011615	1.338824	1.36527	1.246777
216	1450	0.01199	0.012755	0.010878	1.250387	1.3539	1.124143
216	1500	0.01199	0.012755	0.01199	1.011864	1.117352	0.930485
216	1510	0.01199	0.012755	0.011244	0.873436	0.927431	0.824105
216	1520	0.012371	0.012755	0.011615	0.781909	0.824105	0.740949
216	1530	0.012755	0.013538	0.01199	0.703826	0.740949	0.670302
216	1540	0.015573	0.019972	0.013144	0.642644	0.670302	0.613206
216	1550	0.013538	0.015157	0.010878	0.586889	0.61563	0.556607
216	1600	0.011244	0.011615	0	0.529435	0.556607	0.505181
216	1610	0.011615	0.012755	0.010878	0.481548	0.505181	0.458531
216	1620	0.011244	0.012755	0	0.434119	0.456469	0.41043
216	1630	0.011615	0.012755	0.010878	0.385575	0.41043	0.35974
216	1640	0.011244	0.012755	0.010516	0.340113	0.35974	0.321073
216	1650	0.011615	0.012755	0.010878	0.30427	0.321073	0.291171
216	1700	0.011244	0.01199	0.010878	0.275224	0.291171	0.262807
216	1710	0.01199	0.013144	0.010516	0.25069	0.262807	0.237415
216	1720	0.01199	0.012755	0.011244	0.227349	0.237415	0.216122
216	1730	0.010878	0.011615	0	0.217509	0.221699	0.211988
216	1740	0	0.010878	0	0.203842	0.211988	0.194546

Appendix M. Continued.

2001 summer event continued.

216	1750	0.011615	0.012755	0	0.186755	0.195861	0.17787
216	1800	0.012755	0.012755	0.012371	0.17043	0.17787	0.161953
216	1810	0.012371	0.012755	0.011615	0.158387	0.163151	0.152532
216	1820	0.011615	0.01199	0.011615	0.146788	0.153694	0.141153
216	1830	0.01199	0.013144	0.011615	0.136725	0.141153	0.130214
216	1840	0.01199	0.012755	0.011615	0.124908	0.130214	0.119711
216	1850	0.011615	0.01199	0.011615	0.114622	0.119711	0.109641
216	1900	0.01199	0.012371	0.011615	0.104768	0.109641	0.100002
216	1910	0.01199	0.012371	0.011615	0.096266	0.100002	0.092599
216	1920	0.011615	0.01199	0.011244	0.089	0.093509	0.085468
216	1930	0.010516	0.011615	0	0.082005	0.085468	0.079452
216	1940	0.010878	0.010878	0	0.076107	0.079452	0.07283
216	1950	0.010878	0.011615	0.010878	0.070416	0.073643	0.066478
216	2000	0.011244	0.011615	0.010878	0.063402	0.067257	0.060394
216	2010	0.011615	0.011615	0.011244	0.058182	0.06189	0.056007
216	2020	0.011615	0.011615	0.011615	0.05387	0.056007	0.051771
216	2030	0.011615	0.011615	0.011615	0.04971	0.052467	0.047686
216	2040	0.011615	0.011615	0.011244	0.045045	0.047686	0.042472
216	2050	0.011244	0.01199	0.010878	0.041211	0.043109	0.038738
216	2100	0.011244	0.011615	0.010878	0.037526	0.03935	0.035154
216	2110	0.010878	0.011244	0.010878	0.034571	0.035741	0.033419
216	2120	0.010878	0.010878	0.010878	0.032848	0.033993	0.031164
216	2130	0.010878	0.011615	0.010878	0.030061	0.032283	0.02844
216	2140	0.010878	0.011244	0.010878	0.02738	0.028976	0.025821
216	2150	0.010878	0.011244	0.010516	0.024301	0.026337	0.02282
216	2200	0.010878	0.011244	0.010516	0.021853	0.023309	0.020436
216	2210	0.010878	0.010878	0.010516	0.019513	0.020904	0.01816
216	2220	0.010878	0.011244	0.010516	0.01728	0.018607	0.015573
216	2230	0.010878	0.011244	0.010516	0.015573	0.015993	0.014338
216	2240	0.010516	0.010878	0.010516	0.013936	0.014745	0.012755
216	2250	0.010516	0.010878	0	0.01199	0.012755	0.011244
216	2300	0.010516	0.010516	0	0.013144	0.013936	0.010878
216	2310	0.010516	0.010516	0	0.013538	0.013936	0.013144
216	2320	0.010516	0.010516	0	0.013538	0.013936	0.012755
216	2330	0	0.019972	0	0.013538	0.013936	0.012755
216	2340	0.012755	0.015573	0	0.013538	0.013936	0.012755
216	2350	0.012371	0.015573	0.010878	0.013144	0.013538	0.012755
217	0	0.010878	0.01199	0	0.013144	0.013538	0.012755
216	2400	0	0.010878	0	0.012755	0.013538	0.012755
217	10	0	0.015573	0	0.012755	0.013144	0.012371
217	20	0	0	0	0.012755	0.012755	0.01199
217	30	0	0	0	0.012371	0.012755	0.01199
217	40	0	0	0	0.012371	0.012755	0.01199
217	50	0	0	0	0.01199	0.012371	0.011615

Appendix M. Continued.

2001 summer event continued.

217	100	0	0	0	0.01199	0.01199	0.01199
217	110	0	0	0	0.01199	0.01199	0.011615
217	120	0	0	0	0.011615	0.01199	0.011244
217	130	0	0	0	0.011615	0.01199	0.011244
217	140	0	0	0	0.011615	0.01199	0.010878
217	150	0	0	0	0.011244	0.011615	0.010878
217	200	0	0	0	0.011244	0.011244	0.010878
217	210	0	0	0	0.010878	0.011244	0.010516
217	220	0	0	0	0.010878	0.011244	0.010516
217	230	0	0	0	0.010878	0.011244	0.010516
217	240	0	0	0	0.010516	0.010878	0
217	250	0	0	0	0.010516	0.010878	0
217	300	0	0	0	0.010516	0.010516	0
217	310	0	0	0	0	0.010516	0
217	320	0	0	0	0	0.010516	0

Appendix M. Continued.

2002 summer event.

177	1640	0	0.035154	0	0	0	0
177	1650	0.038738	0.04375	0.035154	0	0	0
177	1700	0.038738	0.047019	0.035741	0	0	0
177	1710	0.036927	0.03813	0.035741	0	0	0
177	1720	0.036332	0.037526	0.035154	0	0	0
177	1730	0.036332	0.037526	0.035154	0	0	0
177	1740	0.026337	0.035741	0.01728	0	0	0
177	1750	0.015573	0.01728	0.013936	0.30427	2.06687	0
177	1800	0.013538	0.014338	0.012755	1.509995	2.06687	0.740949
177	1810	0.013144	0.013538	0.012755	0.529435	0.730234	0.387457
177	1820	0.012755	0.013538	0.012371	0.324492	0.385575	0.286337
177	1830	0.011615	0.012755	0.010516	0.268978	0.284735	0.253691
177	1840	0	0.010878	0	0.230202	0.253691	0.205188
177	1850	0	0.047019	0	0.186755	0.205188	0.169206
177	1900	0	0	0	0.147928	0.167986	0.124908
177	1910	0	0	0	0.098125	0.12386	0.07446
177	1920	0	0	0	0.056007	0.07446	0.041839
177	1930	0	0	0	0.03061	0.041211	0.021853
177	1940	0	0	0	0.016418	0.021853	0.012371
177	1950	0	0	0	0	0.01199	0
178	2400	0	0	0	0	2.06687	0
179	2400	0	0	0	0	0	0

Appendix N. Compiled hillslope erosion data.

Watershed	Sub-basin	Differences from one period to the next: 1995 Fall	1996 Fall	1997 Spring	1997 Fall	1999 Fall	2000 Fall	2001 Spring	2001 Fall	2002 Spring	2002 Fall	2003 Spring	Total diff over 11 pds Sum
Jensen	1	0.0000	-2.0000	1.0000	-0.5000	-1.1667	-2.0000	2.6667	-0.3333	0.6667	-1.5000	1.0000	-1.1667
Jensen	2	0.1667	-0.6667	-0.5000	-0.5000	-0.8333	-1.1667	2.6667	-0.3333	0.3333	-0.8333	0.6667	1.0000
Jensen	3	-0.6667	0.1667	-1.1667	-0.8333	0.1667	2.0000	-0.6667	-1.0000	1.1667	-1.3333	1.5000	2.3333
Jensen	4	0.3333	-2.5000	0.6667	-0.8333	-4.0000	-0.8333	2.1667	-1.3333	-0.1667	-0.1667	1.3333	-1.3333
Jensen	5	-1.3333	2.1667	-0.1667	-1.3333	-1.2500	-4.2500	6.2500	-1.2500	0.0000	-0.5000	1.1667	4.5000
Jensen	6	-1.1667	0.1667	0.0000	-0.5000	-1.1667	0.0000	1.3333	-1.3333	0.0000	-1.0000	1.0000	3.3333
Jensen	7	0.1667	0.0000	-0.1667	-0.1667	-1.0000	-0.5000	2.3333	0.3333	-0.6667	-1.0000	1.0000	7.3333
Jensen	8	-1.0000	-1.5000	-0.3333	-0.1667	-2.0000	-0.5000	5.6667	-4.8333	-0.3333	-0.3333	0.3333	3.0000
Jensen	9	-1.5000	-3.1667	1.8333	-0.5000	-6.0000	-1.3333	2.1667	0.5000	1.1667	-1.1667	0.8333	1.8333
Jensen	10	0.5000	-1.5000	1.1667	-0.1667	-0.6667	-0.5000	2.3333	-1.3333	0.0000	-5.3333	5.6667	10.1667
Jensen	11	-0.1667	-3.5000	1.5000	-0.5000	-0.3333	-0.6667	2.0000	-1.1667	-5.1667	-1.0000	1.1667	3.1667
Jensen	12	-0.1667	-4.8333	3.6667	-1.1667	0.5000	-0.8333	1.6667	-0.8333	-0.3333	-0.8333	1.0000	9.8333
Mays	1	0.833333	-0.33333	-0.16667	0	0.166667	-1	1.166667	0	-0.66667	-0.66667	0.5	0.8333
Mays	2	0.833333	0.833333	0.666667	-2.5	0.666667	-1.33333	1.5	-0.66667	1.5	-1.83333	1.333333	3.0000
Mays	3	-1.5	0	1.333333	-0.83333	0.333333	-0.83333	1.333333	0	-0.33333	-0.33333	1.166667	3.3333
Mays	4	-0.83333	-0.33333	-0.33333	-0.66667	2.5	-0.5	1.333333	1	0.5	-0.83333	1.333333	7.1667
Mays	5	1.333333	-1.16667	1.166667	-0.66667	0.5	-1.16667	1	0.166667	-0.33333	-0.66667	0.5	5.6667
Mays	6	-3.83333	-1	1.166667	-0.16667	0.833333	-0.66667	1.5	-3.33333	-2.66667	0.5	1.5	-0.1667
Mays	7	-1.83333	0.333333	0.166667	-0.5	0.333333	-0.5	1.5	-0.16667	0.333333	-0.33333	0.166667	6.5000
Mays	8	0.166667	-0.16667	0.666667	-0.5	0.833333	-2.83333	3.333333	-0.66667	-0.66667	-0.33333	0.333333	8.1667
Mays	9	-0.16667	-1.83333	0.5	-0.66667	1.833333	-1.66667	2.166667	0.833333	0.5	-0.5	1.333333	11.3333
Mays	10	-6.83333	1.666667	-0.66667	-0.33333	1.166667	-1.33333	1.5	-0.33333	-1.5	-0.66667	1.166667	3.8333
Mays	11	-2.33333	0	0	-0.33333	0.5	-1.16667	0.833333	0	2	-1.33333	0	9.1667
Mays	12	-0.66667	-0.83333	1	-1	0.333333	-1.66667	1.833333	-0.66667	-0.66667	0.333333	0	10.0000

Appendix O. Hillslope erosion data, statistical output.

Regression

The regression equation is
y = 0.046 + 0.449 x

Predictor	Coef	StDev	T	P
Constant	0.0463	0.2209	0.21	0.839
x	0.4494	0.1770	2.54	0.032

S = 0.7170   R-Sq = 41.7%   R-Sq(adj) = 35.3%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	3.3155	3.3155	6.45	0.032
Residual Error	9	4.6270	0.5141		
Total	10	7.9425			

One-way Analysis of Variance

Analysis of Variance

Source	DF	SS	MS	F	P
Factor	1	0.19	0.19	0.16	0.694
Error	20	24.36	1.22		
Total	21	24.55			

```
                                     Individual 95% CIs For Mean
                                     Based on Pooled StDev
Level        N      Mean    StDev    ----------+---------+---------+--
----
Jensen      11    -0.258    1.281     (------------*------------)
Mays        11    -0.069    0.891         (------------*------------)
                                     ----------+---------+---------+--
----
Pooled StDev =   1.104                       -0.50      0.00      0.50
```

GROUND WATER DEPTH (meters)
Jensen

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1997												
ADH1	0.0	-3.0	0.0	na	0.0	0.0	0.0	na	0.0	na	na	na
ADH2	0.0	0.0	0.0	na	0.0	0.0	0.0	na	0.0	na	na	na
ADH3	-3.4	-2.6	-4.3	na	-6.4	-7.3	-7.5	na	-7.9	na	na	na
ADH4	-4.0	-3.1	-4.8	na	0.0	0.0	0.0	na	0.0	na	na	na
ADH5	-4.0	-3.2	0.0	na	0.0	0.0	0.0	na	0.0	na	na	na
ADH6	0.0	na	0.0	na	0.0	0.0	0.0	na	0.0	na	na	na
1998												
ADH1	na	na	0.0	na	na	na	na	na	na	na	na	na
ADH2	na	na	0.0	na	na	na	na	na	na	na	na	na
ADH3	na	na	-4.6	na	-3.7	-4.1	-6.0	-7.6	na	na	-6.3	na
ADH4	na	na	-5.2	na	-4.2	-4.6	-6.5	na	na	na	na	na
ADH5	na	na	0.0	na	-4.3	na	na	na	na	na	na	na
ADH6	na	na	0.0	na	na	na	na	na	na	na	na	na
1999												
ADH1	0.0	na	-3.4	-2.5	na	na	na	0.0	0.0	na	0.0	0.0
ADH2	0.0	na	0.0	0.0	na	na	na	0.0	0.0	na	0.0	0.0
ADH3	-6.7	na	-3.1	-2.4	na	-6.1	na	-7.5	-7.8	na	-8.1	-8.2
ADH4	0.0	na	-3.6	-2.9	na	-6.5	na	0.0	0.0	na	0.0	0.0
ADH5	0.0	na	-3.4	-2.7	na	na	na	0.0	0.0	na	0.0	0.0
ADH6	0.0	na	0.0	-3.6	na	na	na	0.0	0.0	na	0.0	0.0
2000												
ADH1	na	na	na	0.0	0.0	na	na	na	na	na	na	na
ADH2	na	na	na	0.0	0.0	na	na	na	na	na	na	na
ADH3	na	na	na	-4.1	-3.7	na	-7.2	-7.8		-8.0		-8.2
ADH4	na	na	na	-4.6	-4.2	na	na	na	na	na	na	na
ADH5	na	na	na	0.0	-4.2	na	na	na	na	na	na	na
ADH6	na	na	na	0.0	0.0	na	na	na	na	na	na	na

GROUND WATER DEPTH (meters)
Jensen

	2001											
ADH1	na	na	na	0.0	na	na	na	na	0.0	na	na	na
ADH2	na	na	na	0.0	na	na	na	na	0.0	na	na	na
ADH3	na	na	na	-5.6	na	na	na	na	-8.1	na	na	na
ADH4	na	na	na	0.0	na	na	na	na	0.0	na	na	na
ADH5	na	na	na	0.0	na	na	na	na	0.0	na	na	na
ADH6	na	na	na	0.0	na	na	na	na	0.0	na	na	na
	2002											
ADH1	na	na	na	na	0.0	na	0.0	0.0	na	na	na	na
ADH2	na	na	na	na	0.0	na	0.0	0.0	na	na	na	na
ADH3	na	na	na	na	-5.9	na	-7.3	-7.8	na	na	na	na
ADH4	na	na	na	na	-6.2	na	0.0	0.0	na	na	na	na
ADH5	na	na	na	na	0.0	na	0.0	0.0	na	na	na	-0.1
ADH6	na	na	na	na	0.0	na	0.0	0.0	na	na	na	na
	2003											
ADH1	na	na	na	na	0.0	na	na	na	na	na	na	na
ADH2	na	na	na	na	0.0	na	na	na	na	na	na	na
ADH3	na	na	na	na	-5.9	na	na	na	na	na	na	na
ADH4	na	na	na	na	-6.2	na	na	na	na	na	na	na
ADH5	na	na	-6.2	na	0.0	-7.1	na	na	-8.1	na	na	-0.1
ADH6	na	na	na	na	0.0	na	na	na	na	na	na	na

GROUND WATER DEPTH (meters)
Mays

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1997												
ADH1	0.0	na	0.0	na	na	0.0	0.0	na	0.0	na	na	na
ADH2	0.0	na	0.0	na	0.0	0.0	0.0	na	na	na	na	na
ADH3	na	0.0	0.0	na	0.0	0.0	0.0	na	0.0	na	na	na
ADH4	0.0	na	0.0	na	0.0	0.0	0.0	na	0.0	na	na	na
ADH5	-3.6	-3.7	-3.6	na	-3.7	0.0	0.0	na	0.0	na	na	na
ADH6	0.0	0.0	0.0	na	0.0	0.0	0.0	na	0.0	na	na	na
1998												
ADH1	na	na	na	na	0.0	na	na	0.0	na	na	na	na
ADH2	na	na	na	na	0.0	na	na	0.0	na	na	na	na
ADH3	na	na	na	na	0.0	na	na	0.0	na	na	na	na
ADH4	na	na	na	na	0.0	-4.6	na	0.0	na	na	na	na
ADH5	na	na	-3.6	na	-3.7	-3.4	-3.4	0.0	na	na	na	na
ADH6	na	na	na	na	0.0	na	na	0.0	na	na	na	na
1999												
ADH1	0.0	na	0.0	0.0	na	na	na	0.0	0.0	na	0.0	0.0
ADH2	na	na	na	na	na	na	na	0.0	0.0	na	0.0	0.0
ADH3	na	na	na	0.0	na	na	na	na	0.0	na	0.0	0.0
ADH4	0.0	na	-4.7	-4.7	na	na	na	0.0	0.0	na	0.0	0.0
ADH5	0.0	na	-3.5	-3.4	na	-3.4	na	0.0	0.0	na	0.0	0.0
ADH6	0.0	na	0.0	0.0	na	na	na	0.0	0.0	na	0.0	0.0
2000												
ADH1	na	na	na	0.0	0.0	na	0.0	0.0	na	0.0	na	0.0
ADH2	na	na	na	-1.2	0.0	na	na	0.0	na	0.0	na	0.0
ADH3	na	na	na	0.0	0.0	na	na	0.0	na	0.0	na	0.0
ADH4	na	na	na	0.0	0.0	na	0.0	0.0	na	0.0	na	0.0
ADH5	na	na	na	-3.5	-3.4	na	0.0	0.0	na	0.0	na	na
ADH6	na	na	na	0.0	0.0	na	0.0	0.0	na	0.0	na	0.0

Appendix P. Continued.

GROUND WATER DEPTH (meters)
Mays

	2001											
ADH1	na	na	na	0.0	na	na	na	na	0.0	na	na	na
ADH2	na	na	na	0.0	na	na	na	na	0.0	na	na	na
ADH3	na	na	na	0.0	na	na	na	na	0.0	na	na	na
ADH4	na	na	na	0.0	na	na	na	na	0.0	na	na	na
ADH5	na	na	na	0.0	na	na	na	na	0.0	na	na	na
ADH6	na	na	na	0.0	na	na	na	na	0.0	na	na	na
	2002											
ADH1	na	na	na	na	0.0	na	0.0	0.0	na	na	na	0.0
ADH2	na	na	na	na		na	-1.3	0.0	na	na	na	0.0
ADH3	na	na	na	na	0.0	na	0.0	0.0	na	na	na	0.0
ADH4	na	na	na	na	0.0	na	0.0	0.0	na	na	na	0.0
ADH5	na	na	na	na	-3.6	na	0.0	0.0	na	na	na	0.0
ADH6	na	na	na	na	0.0	na	0.0	0.0	na	na	na	0.0
	2003											
ADH1	na	na	0.0	na	na	na	na	na	0.0	na	na	0.0
ADH2	na	na	0.0	na	na	na	na	na	0.0	na	na	0.0
ADH3	na	na	0.0	na	na	na	na	na	0.0	na	na	0.0
ADH4	na	na	0.0	na	na	na	na	na	0.0	na	na	0.0
ADH5	na	na	0.0	na	na	na	na	na	0.0	na	na	0.0
ADH6	na	na	0.0	na	na	na	na	na	0.0	na	na	0.0

Appendix Q. 18 soil classes associated with the distribution of western juniper. (source: Gedney 1999)

E—Udic cryic soils of the high cascade and Wallowa Mountains
F—Xeric cryic soils of the high plateaus and mountains
G—Xeric cryic soils on pumice mantled forested plateaus
H—Aquic frigid and cryic soils of basins and valleys
K—Xeric mesic soils on forested mountains and hills
L—Xeric mesic soils on terraces and flood plains
M—Xeric mesic soils on grass-shrub upland
O—Xeric frigid soils on forested mountains and plateaus
P—Xeric frigid soils on terraces and flood plains
Q—Xeric frigid soils on grass-shrub uplands
R—Xeric frigid soils on terraces and flood plains
S—Xeric-Aridic mesic soils on terraces and flood plains
T—Xeric-Aridic frigid soils on grass-shrub uplands
U—Aridic-Xeric mesic soils on terraces and flood plains
V—Aridic-Xeric mesic soils on grass-shrub uplands
W—Aridic-Xeric frigid soils on terraces and in basins
X—Aridic-Xeric frigid soils on terraces and in basins
Y—Lava flows